2009 ENVIROTHON CURRENT ISSUE
BIODIVERSITY IN A CHANGING WORLD

Overview

The rich tapestry of life on our planet is the outcome of over 3.5 billion years of evolutionary history. It has been shaped by forces such as: changes in the planet's crust, ice ages, fire, and interaction among species. Now, it is increasingly being altered by humans through our habitat changes to benefit us. The impacts of human activities reach into every corner of the natural world. For instance, between one third and one half of the Earth's land surface has been substantially transformed by agriculture, urbanization, and commercial activities of various kinds; about one quarter of all bird species have been driven to extinction; and more than one half of all accessible surface water, as well as an enormous quantity of groundwater, is diverted for human uses. It is estimated that 25% of all species could go extinct in the next ten years.

These uses have brought unquestionable benefits to human welfare. But the upshot of this growing human domination of the planet is that no ecosystem on Earth is free from pervasive human influence.

The term `biodiversity' is indeed commonly used to describe the number, variety and variability of living organisms. It has become a widespread practice to define biodiversity in terms of genes, species and ecosystems, corresponding to three fundamental levels of biological organization.

It is evident that a certain level of biological diversity is necessary to provide the material basis of human life: at one level to maintain the biosphere as a functioning system and, at another, to provide the basic materials for agriculture and other needs.

Over geological time, all species have a finite span of existence. Species extinction is therefore a natural process, which occurs without the intervention of man. However, it is beyond question that extinctions caused directly or indirectly by man are occurring at a rate, which far exceeds any reasonable estimates of background extinction rates. Management of our ecosystems intended to maintain one facet of biodiversity will not necessarily maintain another facet which may be just as important.

Perhaps because the living world is most widely considered in terms of species, biodiversity is very commonly used as a synonym of species diversity, in particular of `species richness', which is the number of species in a site or habitat. Marine habitats frequently have more different phyla but fewer species than terrestrial habitats. Species diversity in natural habitats is high in warm areas and decreases with increasing latitude and altitude. On land, diversity is also usually higher in areas of high rainfall and lower in drier areas. The richest areas are undoubtedly tropical moist forests. In aquatic areas most life is found near the shoreline.

- Biodiversity changes as man manipulates his environment - is this good or bad?
- Biodiversity changes are a natural process - how does acceleration of our environmental changes affect it?
- Biodiversity has changed or changes as a result of our activities
  A. Habitat Loss (i.e. agricultural, urban sprawl, population growth, etc.)
  B. Natural Disasters
  C. Alterations in Ecosystems (i.e. deforestation, dams, fragmentation, etc.)
  D. Invasive and Non-Native Species
  E. Over-exploitation
  F. Pollution / Pesticides
  G. Global Climate Change

Biodiversity in a Changing World

Learning Objectives

Students will be able to:

1. Define Biodiversity
    A. Species Biodiversity
    B. Ecosystem Biodiversity
    C. Genetic Biodiversity
    D. Cultural Biodiversity

2. Explain the benefits of biodiversity and why they are important.
    A. Economic
    B. Environmental
    C. Medical
    D. Recreational / Social

3. Identify and explain how a changing world impacts soils/land use, aquatic ecology, forestry, and wildlife and the effects these changes have on biodiversity.
    A. Habitat Loss (i.e. agricultural, urban sprawl, population growth, etc.)
    B. Natural Disasters
    C. Alterations in Ecosystems (i.e. deforestation, dams, fragmentation, etc.)
    D. Invasive and Non-Native Species
    E. Over-exploitation
    F. Pollution / Pesticides
    G. Global Climate Change

4. Provide solutions to minimize and /or solve biodiversity loss.

Resources

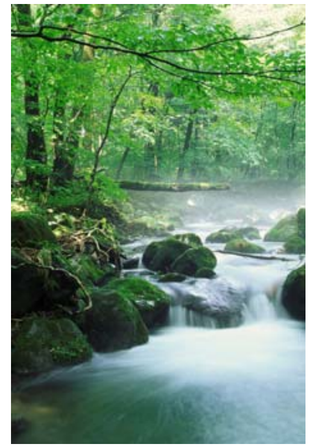
1. Biodiversity in a Changing World – Resource compiled and provided by the PA Envirothon Program (Resources cited at the end of document)

2. Biodiversity Our Living World: Your Life Depends On It!

Learning Enhancement Activity

1. Biodiversity: Earth’s Most Valuable Resource

PENNSYLVANIA OUR PLACE AND ITS PAST



The land we now know as Pennsylvania was a far different place when William Penn arrived on the Delaware River estuary in 1682. Forest spanned all the hills and ridges from the Delaware to the Great Lakes. Streams ran clear and cold, crowded with fish in numbers we can scarcely imagine. Wild pigeons, ducks, and geese darkened the sky and Native hunters lived well on elk and deer.

Primeval Penn's Woods

From Penn's Delaware, north and westward, the land rises gently, seeming to align with the curve of the earth itself. For 50 miles it slopes easily upward. Rain and melting snow flow reluctantly along the serpentine courses of the Schuylkill and the Tulpehocken, the Swatara and the Conestoga. Oaks and tulip poplars, their girths as wide as a train, stand across the hillsides and along the streams, rooted in some of the Earth's most fertile soils. Wild turkeys and deer thrive around the forest openings where the Lenape people grow their squash and corn. Clouds of waterfowl clamor across the skies each spring and autumn.

Farther north, the streams well up as springs in the flank of the great Blue Mountain, underbelly of the Appalachians, arcing across the Piedmont from the Delaware to the southwestern horizon. Only the Susquehanna, Schuylkill, and Lehigh rivers and their larger tributaries breach the long Blue Mountain wall. Silvery American shad, striped bass and eels cram these Atlantic Coast streams with their spawning runs every spring.

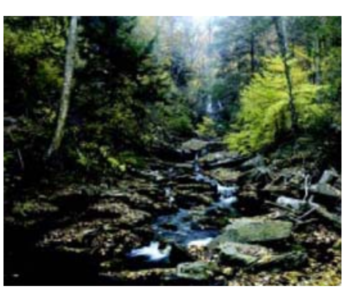
Beyond the Blue Mountain are the endless parallel ridges of the vast Appalachian belt. For hundreds of miles the ridges track one another along parallel courses, flanked by long narrow valleys. These ridges – Tuscarora, Kittatinny, Blacklog, Tussey, Jacks, Nittany, Bald Eagle, and Shade – are the defining topographic signature of Pennsylvania.

In sheltered hollows along the flanks of these ridges stand great beech trees. Passenger pigeons descend in flocks upon the trees to feed on the nutritious nuts, until the birds break the branches under their own great weight.

At the ridges' northeastern limits, gouged long-gone glaciers, stands the Pocono Plateau. The Pocono streams linger under dark spruces in mountain wetlands, then plunge over white cascades to the Delaware far below. Otters chase trout in the beaver dams and far below. Otters chase trout in the beaver dams and eagles and ospreys fish the Delaware pools.

West of the ridges looms the Allegheny Front with its high plateau sprawling northward and west toward Lake Erie and the Ohio Valley. Two-hundred-foot white pines, neighbors to hemlocks of equal size, stud the Front. Spring mornings are cacophony of birdsong.

Elk and bison herds summer here on mountain meadows, and then migrate into the valleys of the Sinnemahoning, Kettle Creek, and the Susquehanna's West Branch to spend the winter where the snows lie less deep.



Streams cleave the plateau into a labyrinth of shadowy canyons, gnawing always deeper into the sedimentary innards of the uplands. Every fall, brook trout swarm and splash in the shallows, fiery red in their spawning dress, recreating their kind across 30,000 square miles of mountain watersheds.

Stretching off to the southwest are the Allegheny Mountains and the region's highest peaks. The first explorers across the Alleghenies report snow on the ridgetops in June, but they are mistaken. The white they see stretching for miles along the heights is the flowering of the American chestnut, prolific producer of nuts that feed deer, bears, turkeys, squirrels, and Native gatherers.

Farther west are the gentler hills of the Ohio Country. Random, endless, they hold a diverse mix of towering trees that blend the forests of north and south. These low hills are the gathering place for great rivers. From the south probes the sometimes-turbid Monongahela, river of "high muddy banks." Meeting it from the north are the cooler waters of the Allegheny, draining the whole western half of the great plateau. They meet at a triangular spit of land pointing down the broad Ohio, westward toward North America's vast heart.

And northward still spreads the inland sea of Lake Erie, teeming with sturgeon, blue pike, walleye, and perch.

Forest to Farm

At first, the changes Penn's colonists brought to the land were scattered and limited. They could clear and cultivate only small patches that quickly returned to forest when abandoned. By the close of the 17th century, Penn's followers had scarcely left a footprint on the land.

Eventually, though, Penn's colony proved more successful than he had probably ever imagined. Early Pennsylvania prospered on the fertile soils and in the hospitable climate of the coastal plain. By the early 1700s, pioneer families were crossing the Blue Mountain on the paths cut by hunters, trappers and traders. They filtered into the valleys between the ridges, and with them they brought change. Every new farm needed fields for crops, and wood for heat, houses, barns, and tools.

Axes rang and the great trees fell. Furnaces that forged the iron for plows and rifles needed charcoal to melt the ore. Each furnace consumed an acre of forest per day. The face of Pennsylvania's settled regions began to change from forest to open ground.

"In one short century of settlement, this wilderness was broken," wrote Peter Matthiessen in *Wildlife in America*. "William Penn was an early defender of trees, and parts of Pennsylvania, not long after his death, already suffered the long-lived effects of ruthless cutting—erosion, flood, parched summers, and poor crops. The clearing indeed, was feverish, for the settlers dreaded the dark monotone of trees, wild beasts and savages they concealed, the wind-borne whispered reminder of a wilderness unconquered. For every tree that was put to use, countless others knew only the manic ring of axes, and, prostrated in their prime, were left to rot in the tangles of second growth."

Forest wildlife disappeared with the trees. Bounties were paid on wolves for most of the colony's first 200 years, and deer were scarce in the settled regions by 1750. Even squirrels were killed for bounty because they raided cornfields to substitute for acorn and chestnut mast no longer so abundant in the cutover forests. As early as 1731 naturalist Mark Catesby reported that "incredible numbers" of passenger pigeons were shot from rooftops in Philadelphia.

Boom Times

The Civil War and the Industrial Revolution spurred the exploitation of Pennsylvania's forests and game. Miners opened the coal fields to fuel the factories. The demand for timber exploded. The great hemlock forests of the upper Susquehanna were felled for the bark alone to extract the tannin for making leather, the broad trunks left molding on the hills.

By 1850 the nation's most fevered logging shifted from Maine and New England to northern Pennsylvania, and from then until 1870 Pennsylvania led all the states in the production of sawtimber.

Native elk had disappeared from Pennsylvania by 1870, and the original woods bison were long gone. Wolves and mountain lions were both extinct in the state by the dawn of the 20th century. Forest birds such as wild turkeys, barred owls, blackburnian warblers, and pileated woodpeckers declined rapidly as the old-growth forests fell. Beaver, otter, marten, mink, and fisher were trapped and shot without regulation, their numbers shrinking along with the forest in which they lived.

By the time the log boom reached the Clarion and Allegheny rivers in the 1860s, the world's first commercial petroleum industry fledged in Crawford County and quickly spread to Venango and other counties. Wooden pipelines burst and spewed crude oil into streams that fed the Allegheny River, and oil barges capsized in floods or were crushed by ice, spilling oil and suffocating the life from the streams.

Salt brine from wells seeped into creeks, killing trout and smallmouth bass.

Downriver at the spit of land pointing west down the Ohio, Pittsburgh's industrial might had begun to blossom. Mill smoke blackened the sky, and sludge, acid, and other wastes flowed free into the now famed "Three Rivers."

The harshest changes occurred in the rivers and streams. Rain sloughed the soil from the naked hills where roots had once held it in place. And sulfur, buried beneath the hills with the coal for 300 million years, combined with water and air when the mines were opened, forming sulfuric acid. It flowed from the mines to poison streams and rivers from the Ohio to the upper Susquehanna.

Not satisfied with the useful and durable wood and abundant nuts of the native American chestnut tree, ambitious horticulturists imported Asian chestnut trees into New England in 1904. The Asian tree carried a fungus under the bark with which it had coexisted for thousands of years. The American chestnut was alike enough to the Asian tree to serve as a fungal host, but the native chestnut could not fight off the blight's stranglehold. The blight spread quickly down the Appalachians and by 1920 had rendered one of the most widespread and beneficial trees in the original forest nearly extinct.

Resilience and Renewal

With the frontier in the past, and no new lands to harness, Pennsylvanians settled into lives in small towns, on farms, and industrial towns clustered along the rivers near the state's large cities. In the early 1900s, the log boom moved on into West Virginia and the Great Lakes states, and the earth began to reveal its resilience.

Freed from constant cutting, surviving tree seedlings grew large enough to drop an annual carpet of leaves to the impoverished ground. Gradually, forests returned to Pennsylvania's hills.

The new forest was different; there were fewer pines and hemlocks, and the once dominant chestnut was reduced to thickets of sprouts from the still-living roots. But oaks seized the vacant niches and thrived. Oak forests clad the ridges, especially in southern Pennsylvania, uninterrupted for miles.

By the 1930s these new woodlands were beginning to offer some of the benefits of the forests of old. Watersheds stabilized, streams again ran clear and the cycles of flood and drought became less severe. Warblers and thrushes returned to the forest canopy and grouse and deer thrived in the undergrowth of the returning woods. Though vibrant and booming with industry, Pennsylvania's urbanized areas still occupied a tiny percentage of the land early in the 20th century.

White-tailed deer were ideally suited to life in the new kind of forest. More adaptable than the elk and bison, deer thrived on the abundant browse and the acorn mast that rained down on the ground each autumn. Deer could also live close to settlements and farms. In the absence of cougars and wolves to trim their numbers, deer herds swelled well beyond the numbers that William Penn encountered along the Delaware.

New Stewards Awakened

This rebirth of Pennsylvania's forests and the return of much of our wildlife is a tribute to the resilience of nature. Wildlife recovery also was helped by a new Pennsylvania conservation movement that took hold by the late 1800s.

As early as 1866, concern was spreading for the declining shad runs in the Susquehanna basin. In that year the General Assembly passed and Governor Andrew G. Curtin signed a law establishing the position of Commissioner of Fisheries of the Commonwealth of Pennsylvania. The Commissioner post was later expanded to establish the Pennsylvania Fish Commission, one of the oldest fisheries conservation agencies in the United States. In 1895 the Legislature established the Bureau of Forestry, founded principally to fight fires and plant trees. The Game Commission was organized in the same year to protect and enhance what was left of Penn's Woods wildlife.

In 1898 the state purchased a 40,000-acre tract as the first state forest reserve, forerunner of today's two million-acre state forest system. The first state park was established at Mont Alto in 1902 and Pennsylvanians began to think of forests as a source of recreation as well as timber.

In 1920 the Game Commission began to purchase land for wildlife habitat and public hunting, and the U.S. Forest Service made the first acquisitions in Elk, Forest, McKean and Warren counties that would eventually become the Allegheny National Forest.

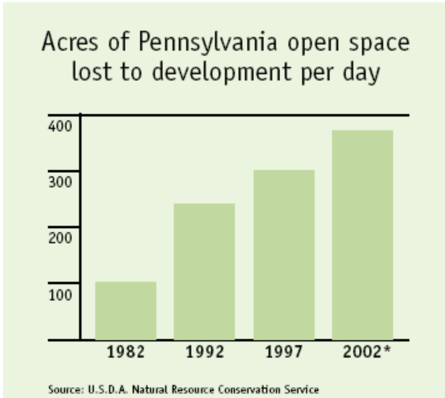
Our Wildlife "Industry"

Today, Pennsylvania is one of the premier outdoor recreation states in the nation. A million Pennsylvanians enjoy a rich tradition of hunting for deer, bear, wild turkey, grouse, rabbits, pheasants, and squirrels. Nearly a million people fish Pennsylvania's lakes and streams, and millions more camp, hike the trails, canoe the rivers, or enjoy the outdoors through photography, feeding birds, or watching wildlife at parks or near their homes.

Wildlife is a multi-billion dollar "industry" in Pennsylvania. Hunters spend 14 million days afield each year in the state and spend a billion dollars on travel, equipment, lodging, and food. Pennsylvania's streams and lakes provide 18 million days of fishing each year and anglers churn 800 million dollars directly into the state's economy. Pennsylvanians devote 19 million days and spend a billion dollars pursuing glimpses or photographs of the state's elk herd, waterfowl, bald eagles, and songbirds. In 2001 alone, one million people visited Pennsylvania woodlands for recreation and 3.4 million participated in watchable wildlife recreation across the state.

Nearly half (45 percent) of all Pennsylvania residents participate in some form of recreation directly linked to wildlife and wildlife habitat. Combined, the total annual impact on the state's economy generated by hunting, fishing, and wildlife-related recreation approaches $6 billion. Sales and income tax revenue from fishing tackle purchases alone nets Pennsylvania $50 million every year, and sales taxes generated by wildlife-watching bring $70 million into the state general fund annually.

Pennsylvanians' kinship with the forests, streams and wildlife is a unique aspect of life here. That kinship is manifest in many ways—on the calendars of some rural school districts, where students and teachers have the first day of deer season off to enjoy the hunt, in the success of small businesses that rely on hunters and fishermen, along whitewater rivers where thousands of urban dwellers ride the rapids to renew their bond with the land, and in the valued Pennsylvania tradition of sharing a mountain campsite with family and friends.



New Threats Looming

Today, our wild lands, open spaces and outdoor traditions, are threatened by a new kind of change, more irreversible than any endured in the past. It is a change that banishes wild things and wild places from its path that rends apart established communities and neighborhoods, and threatens the diversity of life around us. The new change sweeping across Pennsylvania's landscape is unplanned and unchecked urbanizing sprawl, gobbling up countryside at a rate that has tripled in the past two decades. Rural and forested habitats are being converted to other uses at a rate that exceeds the area of Dauphin County, 332,800 acres, every three years.

In the three centuries that followed Penn's landing on the Delaware in 1682, three million acres of Pennsylvania landscape were converted to urban uses, concentrated in downtown sectors of cities and towns.

But in the past two decades (1982–2002) another one million acres of woods, fields, marshes, and mountainsides have been irreversibly converted to other uses, creating a new kind of landscape we know as sprawl.

The Pennsylvania 21st Century Environment Commission identified urban sprawl as a major environmental issue in this state.

In 1982 Pennsylvania was losing 100 acres per day to sprawl. Today that rate is estimated to be more than 350 acres per day and may be accelerating. Brought together in one place, these developed tracts would cover an area the size of Delaware County, 122,000 acres, every 12 months.

These are lands that may be changed forever. They may never again grow a crop of soybeans or corn. They are lands where no Pennsylvanian may ever again call a turkey or follow a rabbit dog through blackberry thickets. They are lands that have lost the sights, sounds, smells and experiences that make rural Pennsylvania different from the suburbs of Phoenix, Washington, Atlanta, or Dallas.

Unlike the forests cut over in the logging boom of the 1800s, these lost habitats may never recover. Sprawl is a one-way change. It is permanent within the scale of our experience. Once wetlands are filled, once woodlands are bulldozed, graded and paved, their value as habitat and open space is seldom recovered.

And as our woodlands, fields, and wetlands dwindle, so do our choices for the kind of Pennsylvania we will leave to our children.

As we watch forests and fertile fields changed into housing lots and shopping malls, those wild places that remain are besieged by yet more threats. Invasive exotic species of plants, birds, and insects threaten some of our most cherished icons of Pennsylvania's outdoors. The eastern hemlock, our own state tree, is threatened by the woolly adelgid, an exotic introduced insect. This pest is killing stately stands of hemlocks across the eastern third of the state, and the scourge is spreading. Invasive exotic weeds crowd our best-loved wildflowers from habitats statewide, and accidentally introduced aquatic life such as zebra mussels threaten the ecosystems of lakes and rivers.

Our last large tracts of forest are being fragmented into ever-smaller blocks by roads, towers, rights-of-way, and development. Deer herds that adapts well to the changing landscape are over-browsing remaining forest, eliminating shrubs, wildflowers, and seedling trees over wide regions of the state.

Acid rain and snow continues to fall on our streams and forests, changing the chemistry of the soil itself. Climate change caused by fossil fuel combustion may soon challenge the survival of northern and upland habitats.

Unless we, as a state, can find a way to understand, value, and conserve our wild lands, we face a future that may offer only a shadow of the outdoor heritage we have always enjoyed. The next few years may be our last chance to save the best part of our home, Penn's Woods.[23]

BIODIVERSITY

Understanding and Conserving the Web of Life

Our planet is literally teeming with life. An amazing variety of habitats, people, plants, and animals—everything from penguins to peas and bacteria to buffalo—are all interconnected in a fragile web of life we call "biodiversity." And every member is essential to keeping this web in balance.[1]

What's the problem?

To date, about 1.4 million species have been identified, and researchers estimate that millions more have yet to be counted…but unfortunately, time is running out. Thousands of species may be vanishing each year as a result of pollution, over-harvesting, habitat degradation, and other human actions.[1]

Why should we care?

Extinction isn't just a loss for science; it's a loss for us. We depend upon biodiversity in our everyday lives to supply us with a healthy environment and many natural materials that are sources for food, medicine, and other economically important products.[1]

INVESTIGATE BIODIVERSITY

Today, biodiversity research has taken on a new urgency. What's all the fuss about? Unique species—from medicinal plants in China to butterflies in Illinois—are disappearing at an alarming pace around the world. As the extinction rate speeds up, we're losing not only many well-known, valuable plants and animals, but also an untold number of species we know nothing about.

Knowledge about species, past environments, and evolutionary relationships is vital to understanding and protecting the biological diversity of life on Earth has been the mission of many scientists for more than a century. Through their efforts, we now know much more about how plants, animals, and people interact with and affect one another in our planet's fragile web of life.[1]

THE BASICS OF BIODIVERSITY

The words "biodiversity" and "conservation" make headline news regularly, but how much do we really understand the meaning of these terms and their impact on our world?

Part of the problem is that our daily lives isolate us from nature. We no longer have firsthand experience with the way the world works—and this lack of knowledge may be catching up with us.

Our challenge now is to learn as much as we can about the part we play in this complex and interdependent web of life. By gaining new perspectives on our place in the natural world, we can create a more responsible society that will empathize with other living things and protect our planet's natural resources.[1]

What is Biodiversity?

The term biodiversity is short for "biological diversity." It's the astounding variety of life on Earth—the plants, animals, habitats, and human cultures that populate the planet. And it's all the interconnections that support and link these living things in a fragile web of life.

Only in the past few decades have we begun to realize the amazing abundance and variety of life we coexist with…and how many more species are yet to be discovered!

And only recently have we truly begun to understand the interdependent relationships shared by all living things. The web of life is like a house of cards — remove one member and the entire system may suffer.[1]

Biodiversity includes:

Species Diversity - the differences within and between the numbers and kinds of species (plants, animals, and other forms of life) that share our world—and the interactions between these species.[1, 2]

Biodiversity includes all organisms, great and small—from amoebas to elephants—that currently exist or have ever existed on our planet. So far, scientists have identified and named more than 1.4 million living species, including approximately:

- 270,000 species of plants
- 72,000 species of fungi
- 950,000 species of insects
- 19,000 species of fish
- 10,500 species of reptiles and amphibians
- 9,000 species of birds
- 4,000 species of mammals

Consider that these numbers don't even include the thousands of mollusks, worms, spiders, algae, and other microorganisms that share the planet with us!

Scientists think there are still millions more species yet to be discovered. And these species are all interconnected and interdependent upon one another in many ways yet to be revealed.[1]

Present Species Diversity in Pennsylvania – We share Pennsylvania with at least 25,000 known native and non-native species. These species can be grouped into seven general categories: vertebrates, invertebrates, vascular plants, nonvascular plants, fungi, and bacteria and other microorganisms.

The number of species in Pennsylvania is not constant. Over geological time, many species died out and were replaced on new ones, gradually shaping the composition and structure of today's flora and fauna. While human activities, particularly habitat destruction, have led to a reduction in native species diversity, natural forces, such as climate change, also have altered biodiversity in Pennsylvania.

Over the past 860,000 years, there have been eight episodes of global cooling severe enough to cover part of Pennsylvania in ice year-round. The interglacial period that occurred approximately 128,000 to 67,000 years ago is particularly interesting because it was most like the present one, except human influence was absent. Most species now native to the state were probably present, but they lived side-by-side with species long absent. For example, white-tailed deer, elk, and moose shared the Pennsylvania landscape with two extinct deer species, three peccaries, giant horse, two tapirs, black bear-sized beaver, two elephant-sized ground sloths, American mastodon, and woolly mammoth. The predators stalking them included black bear, timber wolf, and mountain lion as well as three other wild dog species, three other bears, two cheetahs, and jaguar.[8]

Ecosystem Diversity – all the different habitats, biological communities, and ecological processes where these plants, animals, and other organisms live and evolve—and the interconnections between them.[1, 2]

Biodiversity occurs in natural communities made up of interacting groups of living things that thrive and depend upon one another in a particular habitat or geographic region.

The local tallgrass prairies of Illinois, the dense rainforests of the Philippine islands, and the coral reefs of the Caribbean are all examples of different ecosystems where unique species live and evolve.

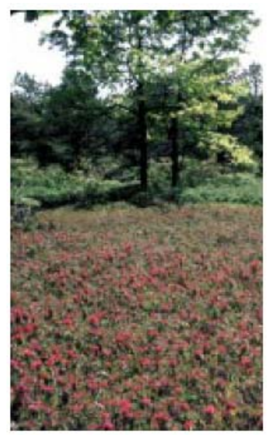
These ecosystems don't just provide habitats for plants and animals; they also benefit humans by providing a variety of services. For example, wetlands help filter ground water and control flooding, while rainforests purify the air we breathe and supply our world with oxygen.[1, 2]

Pennsylvania's landscape may be separated into seven major categories – forests, grasslands and open areas, barrens, subterranean, wetlands, aquatic, and disturbed.

Forests, by far, are the largest community type in Pennsylvania. When Europeans first arrived in Pennsylvania, more than 80 percent of the landscape was forested. Large expanses were covered by hemlock, beech, and pine in the northern part of the state and by oak, chestnut, and hickory in the ridges, and valleys. [8]

- Pennsylvania still has about 17 million acres of forest, but the age, structure, and composition of these forests have changed since Europeans first settled the state.
- There are fewer hemlock and white pine today.
- Chestnut is gone except in isolated areas.
- Wild black cherry is a major timber tree.
- Little old growth forest remains due to extensive logging in the late 1800s and early 1900s to build the infrastructure of a growing nation.
- Except for a 4,200-acre tract on the Allegheny Plateau, nearly all of the virgin forest is in fragments of less than 250 acres.
- Most of the forest ranges from 80 to 100 years old and is a uniform maturity.

Natural grasslands are rare in Pennsylvania and many in existence at the time of European settlement were the result of vegetation management with fire by American Indians. The only patches of true prairie occur in western Pennsylvania and are extensions of the Midwestern prairie. Most open areas today are typically a result of disturbance by man, including revegetated strip mines, old fields, mountain balds, and forest openings. [8]



Barren comprise about 3 percent of Pennsylvania's land cover. They are represented by sparsely vegetated gravel/rock outcrops and slopes, grasslands, savannas, thickets, and scrub woodlands. Most barrens have shallow, nutrient-poor-soils and are located in exposed ridges or slopes where wind conditions and temperatures can become extreme and fire is frequent. Because of these harsh conditions, barrens often contain highly adapted, rare species of plants and animals and, thus, although small in extend, barrens are critical in terms of biodiversity. The serpentine barrens in southeastern Pennsylvania contain the largest number of endangered plant and animal species in the state. [8]

Subterranean areas, such as caves, are often overlooked as a habitat type. Caves, with their unique formations, temperatures, moisture conditions, and air dynamics provide an important, but fragile, habitat for many invertebrates and vertebrates. Some invertebrates in Pennsylvania caves are found nowhere else in the world. Pennsylvania's cave also provide habitat for many bats, including the state and federally endangered Indiana bat and other small mammals such as eastern woodrat, which is listed as threatened in the state.[8]

Wetlands are transitional areas between upland and open-water habitats and are delineated on the basis of vegetation, hydrology, and soils. Most of Pennsylvania's more than 400,000 acres of wetlands are located in Crawford, Erie, Monroe, Pike, Wayne, Luzerne, and Mercer counties. Wetlands include *marshes* (dominated by herbaceous plants), *swamps* (dominated by trees), and *scrub-shrub* wetlands. Wetlands provide important habitat for plants and animals, and are home to some of the rarest species in the state, including bog turtles and spreading globe-flower. More than 50 percent of Pennsylvania's original wetlands have been lost or substantially degraded by filling, draining, or conversion to ponds. From 1950 through 1970, 1,200 acres of wetlands were disturbed each year, resulting in the loss of wetland plant and animal species. [8]

Aquatic communities are habitats that continually maintain open water and include *tidal, riverine,* and *lake habitats.* These areas provide food and shelter to a diversity of plants and animals.

In Pennsylvania, *tidal wetlands* are limited to the lower Delaware River and its tributaries.

With more than 83,000 miles of streams – second only to Alaska in the number of stream miles – Pennsylvania has abundant *riverine habitats*. Many of these miles, however, have been adversely affected by industrial practices, including more than 3,100 miles impaired by abandoned mine drainage and 3,116 miles by agriculture. Of the almost 53,000 miles of rivers and streams surveyed for biological health, more than 44,000 miles support fish and aquatic uses while approximately 8,000 miles are impaired.

Most of Pennsylvania's *natural lakes* are found in the northwestern and northeastern parts of the state. Of the 65,483 acres of lakes assessed statewide for biological health, 60.1 percent were listed as impaired, with agriculture accounting for most of the damage (13,014 acres). Although often overlooked, small seasonal pools of less than one-half acre play an important role as breeding grounds for many amphibians, insects, and other aquatic invertebrates in the state. [8]

Disturbed communities, which include cultivated land, roadsides, developed land, and backyards, are increasing at a greater rate than any other community type in Pennsylvania. In 1989, there were almost 2 million acres of lawn/turfgrass in Pennsylvania – an area that would cover the states of Delaware and Rhode Island combined. Even though disturbed habitats contain high proportions of alien species, they are important as home to a variety of native species, including woodchucks, deer, mice, meadow voles, chipping sparrows, and goldenrods. Although primarily habitats for very common species, these areas can contribute to maintaining wildlife and wild plants in the state. Edges – transition zones where two habitats come together, such as where a forest meets a field – provide a particularly rich diversity of food and shelter for wildlife.[8]

Facts About Endangered Species

More than 800 species in Pennsylvania are considered to be of conservation concern including plants and animals whose survival status is at risk not only within Pennsylvania, but also beyond our borders. [8]

- Currently, 130 species still living in the state are ranked as globally endangered, threatened, or rare. [8]
- The U.S. Fish and Wildlife Service tracks 17 species in Pennsylvania listed s endangered or threatened under the federal Endangered Species Act. [8]

Many of the most critically endangered species are found in wetlands and other aquatic habitats.[8]

- About half of Pennsylvania's 65 species of freshwater mussels are endangered or gone from Pennsylvania. [8]
- Nearly 30 percent of Pennsylvania fish species are of conservation concern, including 28 listed as endangered. [8]
- Almost 60 percent of endangered and threatened species of vascular plants in Pennsylvania grow in water-dependent habitats. [8]

Human Influence – Gradual change has been the hallmark of biological communities, but the appearance of one new species – humans – approximately 13,000 years ago resulted in abrupt changes in species composition. [8]

EVENT	IMPACT
13,000 Years Ago **Arrival of humans in the New World**	• More than two dozen species of large mammals, including woolly mammoths, American mastodons, and giant beavers, became extinct within a few centuries of the arrival of humans to the area that became Pennsylvania. • People's use of fire affected biodiversity. Oak-dominated forests and native grasslands most likely are products of large-scale burning by American Indians.
1600s **A small group of Swedes set up a colony in present-day Delaware County**	• Europeans introduced new plants, animals, and microbes. • Forests were cut down and converted to agricultural land. • Natural resources were exploited far more intensively than by previous human occupants.
Mid-1800s **Industrialization rapidly accelerated the pace of change**	• Since the mid-1800s, at least 150 species have been eliminated from Pennsylvania. • Thousands of non-native species have been introduced, including 1,281 plants – more than 37 percent of the current flora – and 152 invertebrates. • Newly introduced species have often had a destructive impact on native organisms and natural ecosystems.
20th Century **Human populations continue to expand throughout Pennsylvania**	• Landscape changes occurred, including urbanization and large-scale mining and agriculture. • Natural fires were suppressed. • Use of natural resources by humans has increased to an all-time high. • Efforts to conserve biodiversity were initiated in the early 1900s and continue to this day.

Genetic Diversity - the inherited traits that distinguish one species from another, including all of the different genes contained in all individual plants, animals, fungi, and microorganism. It occurs within a species as well as between species. [1, 2]

Biodiversity includes the inherited biological traits that are carried within the DNA of each species or individual's genes.

Genetic diversity can be seen in the various colors and shapes of apples in the grocery store, the differences in human hair and eye color, and in the subtle changes in song or markings within a particular species of bird.

Maintaining genetic diversity within a group of plants, animals, or people is extremely important because it allows populations to adapt when changes occur in their environment. If populations become too small, genetic diversity is lost. Populations that have little genetic diversity are often vulnerable to outbreaks of disease or pest infestations. Very little is known about the genetic diversity of individual species in Pennsylvania. Only a few genetic studies have been completed, and these have focused mainly on species of conservation concern. [1, 8]

Cultural Diversity - the mosaic of human cultures that both influence and are affected by the natural world

Biodiversity includes the vast array of human beliefs, knowledge, traditions, customs, and languages that create the framework for society. Although all humans belong to one species (*homo sapiens*), our species is made up of thousands of different cultures.

These cultures often determine how people interact with nature. For example, religious beliefs can affect a community's diet and the crops they choose to grow (and how they grow them), while social status within a group can affect a culture's land-management practices.

Similarly, the natural world can profoundly influence the development of human societies. For example, certain cultural lifestyles represent "solutions" to the problems of survival in a particular habitat, such as the nomadic tradition of desert dwellers. Essentially, cultural diversity helps people adapt to changing conditions in their environment.[1]

THE BASICS OF BIODIVERSITY

Why is biodiversity important?

The diversity of life enriches the quality of our lives in ways that are not easy to quantify. Biodiversity is intrinsically valuable and is important for our emotional, psychological, and spiritual well-being. Some consider that it is an important human responsibility to be stewards for the rest of the world's living organisms.

Diversity breeds diversity. Having a diverse array of living organisms allows other organisms to take advantage of the resources provided. For example, trees provide habitat and nutrients for birds, insects, other plants and animals, fungi, and microbes.

Humans have always depended on the Earth's biodiversity for food, shelter, and health. Biological resources that provide goods for human use include:

- **Food** – species that are hunted, fished, and gathered, as well as those cultivated for agriculture, forestry, and aquaculture;
- **Shelter and warmth** – timber and other forest products and fibers such as wool and cotton;
- **Medicines** – both traditional medicines and those synthesized from biological resources and processes.

Biodiversity also supplies indirect services to humans which are often taken for granted. These include drinkable water, clean air, and fertile soils. The loss of populations, species, or groups of species from an ecosystem can upset its normal function and disrupt these ecological services. Recent declines in honeybee populations may result in a loss of pollination for fruit crops and flowers.

Biodiversity provides medical models for research into solving human health problems. For example, researchers are looking at how seals, whales, and penguins use oxygen during deep-water dives for clues to treat people who suffer strokes, shock, and lung disease.

The Earth's biodiversity contributes to the productivity of natural and agricultural systems. Insects, bats, birds, and other animals serve as pollinators. Parasites and predators can act as natural pest controls. Various organisms are responsible for recycling organic materials and maintaining the productivity of soil.

Every component of biodiversity—from microorganism to grizzly bear—is part of the web of life. Entire ecosystems can be altered by the loss of one component.[1, 2]

BIODIVERSITY'S VALUE INCLUDES:

Economic Importance: the natural products that sustain global trade [1]
Environmental Importance: the natural systems that balance ecological health [1]
Medical Importance: the plants, animals, and microorganisms that benefit society [1]
Recreational Importance: the array opportunities and aesthetic values that generate income [17]

We're economically dependent upon biodiversity.

A huge number of natural products not only supply us with food, but also boost our economy. An estimated 80,000 edible plants are found in the world, and one in every three mouthfuls of the food you swallow is prepared from plants pollinated by wild insects and animals.[1]

For example, more than 40 crops cultivated in the United States (and valued at more the $30 billion dollars annually) rely on a diverse population of insects for pollination—insects that can be harmed by pesticides. And building materials, and other natural resources we depend upon financially! [1]

In addition, our national parks not only improve our quality of life; they also generate more than 400,000 jobs and more than $28 billion in economic activity each year. If you're lucky enough to live next to a park or a nature preserve, you'll also notice an increase in your property value, too. The net economic benefits of biodiversity are estimated to be at least $3 trillion per year, or 11 percent of the annual world economic output. Biodiversity conservation activities not only protect the environment in developing countries but also have significant economic value to the United States.[1, 3]

We're environmentally dependent upon biodiversity.

We know that biodiversity is crucial to sustaining the environment around us. We've learned that trees and other plants diminish the risks of climate change and global warming by removing carbon dioxide from the atmosphere. When we remove trees and plants, unfortunately the threat of flooding, mudslides, and pollution increases. And we're now just beginning to understand the roles that different species play in this process.[1]

Each species plays a role in the survival of the other partners, and together they maintain the life of their natural community. In a group of natural communities, or an "ecosystem," the complex interactions of living organisms with their environments sustain their life-support system. When species are lost, ecosystems cannot function properly, and the lives of all partners are disturbed.[8]

We're medically dependent upon biodiversity.

Approximately 50 percent of our medicines contain compounds that are obtained from or modeled on substances extracted from the natural world. More than 3,000 antibiotics—such as penicillin, which comes from a certain type of mold—were originally derived from microorganisms.

All species, including those yet undiscovered or currently perceived as "worthless," hold the potential to provide us with life-saving products. [1]

Of the top-selling 150 prescription drugs in the United States, 79% gave there origins in nature. Many synthetic drugs, including aspirin, were first discovered in wild plants and animals. Roughly 199 pure chemical substances extracted from some 90 species of higher plants are used in pharmaceuticals around the world.

Traditional medicine, which relies on species of wild and cultivated plants, forms the basis of primary health care for about 80% of all people living in developing countries. In the United States, traditional medicine and other alternative health systems are gaining in acceptance. Each year, the U.S. imports more than $20 million of rainforest plants valued for their medicinal properties.

Despite such widespread popularity, only 3% of the 250,000 described species of vascular plants have been screened for their chemical compounds. Of those that have been screened, some show dramatic promise. For example, Taxol, a new drug developed from the Pacific yew tree, is being used to treat ovarian cancer.

In 1960, a child with leukemia had a 1 on 5 chance of remission. Now, thanks to anti-cancer drugs developed from a compound discovered in wild periwinkle plants, the same child's chance of survival has increased to 80%.[17]

We're recreationally dependent upon biodiversity.
In addition to protecting our future food supply, health, and environment, biodiversity provides an array of recreational opportunities and aesthetic value. In 1991, recreation associated with wild birds alone generated nearly $20 million in economic activity and 250,000 jobs in the United States, exceeding many Fortune 500 companies. Saltwater recreational fishing in the U.S. generates more than $15 billion annually in economic activity and provides over 200,000 full-time jobs.

U.S. parks brought in $3.2 billion from visitors in 1986. That same year, tourism in Kenya amounted to $400 million. In that country, the economic value of viewing elephants alone totaled $25 million in 1989. These large economic revenues reflect the high value people place on recreation involving biodiversity.[17]

What's the status of biodiversity?

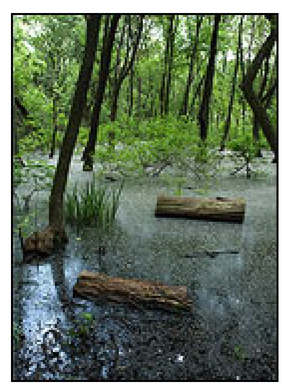
Around the world, habitats are shrinking due to human activities like farming, logging, and building. This habitat destruction has caused species to go extinct, resulting in a loss of biodiversity.

But the losses may be greater than we know. Scientists have described just over one million species and believe millions more await discovery. How many species will go extinct before we know they exist or what benefits they provide?[1]

Biodiversity's value includes:

Biodiversity has been damaged – habitat destruction is unbalancing natural systems and disrupting the web of life.

Many human actions, if not properly managed, can cause pollution and overuse resources, which destroys habitats. Loss of these habitats—the ecosystems where these plants and animals get their water, food, and shelter—is the primary reason for biodiversity's decline.



By over-fishing, cutting down forests for lumber, and filling in wetlands for urban development, we change the natural environment for the species that live there. Plants and animals die off, not only because they're removed, but because their complex interactions are interrupted.[1]

Biodiversity is in danger of disappearing entirely – the extinction rate is speeding up as a result.
Scientists believe that extinction is speeding up at an alarming rate. Thousands of species may be vanishing each year.

Some experts estimate that a major extinction on a scale approximating the loss of dinosaurs may be approaching—and it would be the first ever caused by human activity. Once a species has been lost, it's lost forever, and with it, the crucial role it played in the web of life.[1]

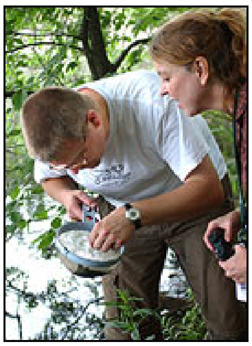
How can we protect biodiversity?

Science and conservation go hand in hand. We need to understand how our actions affect the creatures and habitats around us to learn how to properly preserve them.

Many scientists work in laboratories and at field sites around the world documenting changes in biodiversity and designing ways to protect it. Ecologists study the natural changes in biodiversity at the genetic, species, and ecosystem levels. This allows them to evaluate human impact by comparing natural processes to human-induced changes.[1]

Ecologists also play a prominent role in researching the conservation, restoration, and use of biodiversity and related ecosystem processes. Some ecologists investigate the effects of different land uses and management practices. Restoration ecologists are developing rationale and methodologies for rehabilitating or restoring damaged habitats and for reintroducing native species. Another important area of ecological research is understanding the implications of global climate change for biodiversity conservation.[3]

Successful conservation includes:



Discovery and Inventory:
First, scientists determine the condition of a site by counting the species they find to learn what plants and animals live there and how they depend upon their habitats.[1]

Analysis and Protection:
Next, scientists use the information they gather to design conservation strategies that protect areas with important biodiversity.[1]

Training and Capacity-building:
Then, scientists share what they have learned by educating future scientists and working with local citizens, scientists, and government officials to implement management plans. Conserving biodiversity is especially crucial in developing countries where people's livelihoods are directly dependent on natural resources such as forests, fisheries, and wildlife.

Many organizations, such as USAID, Field Museum Scientists, PA Biodiversity Partnership, and the Center for Biodiversity and Conservation, support conservation activities in numerous countries, seeking to maintain the variety of species and the habitats in which they occur. These organizations work with communities, non-governmental organizations, and governments to develop environmental policies that conserve biodiversity and, at the same time, sustain local livelihoods. They invest in building the capacity of foreign governments, non-governmental organizations, and communities to better manage protected areas. In addition, they promote enterprise-based conservation initiatives (such as eco-tourism), which provide economic benefits from the preservation of biological resources. To complement these activities, the groups foster greater public awareness of conservation issues by supporting the development of outreach and environmental education programs.[1, 3]

WHAT ARE THE THREATS TO BIODIVERSITY?

The loss of biodiversity is a significant issue for scientists and policy-makers and the topic is finding its way into living rooms and classrooms. Species are becoming extinct at the fastest rate known in geological history and most of these extinctions have been tied to human activity.

Habitat loss and destruction, usually as a direct result of human activity and population growth, is a major force in the loss of species, populations, and ecosystems.

Alterations in ecosystem composition, such as the loss or decline of a species, can lead to a loss of biodiversity. For example, efforts to eliminate coyotes in the canyons of southern California are linked to decreases in song bird populations in the area. As coyote populations were reduced, the populations of their prey, primarily raccoons, increased. Since raccoons eat bird eggs, fewer coyotes led to more raccoons eating more eggs, resulting in fewer song birds.

The **introduction of invasive (non-native) species** can disrupt entire ecosystems and impact populations of native plants or animals. These invaders can adversely affect native species by eating them, infecting them, competing with them, or mating with them.

The **over-exploitation** (over-hunting, over-fishing, or over-collecting) of a species or population can lead to its demise.

Pollution and the use of **pesticides** can have unintended effects on the environment.

Global climate change can alter environmental conditions. Species and populations may be lost if they are unable to adapt to new conditions or relocate.[3]

Pennsylvania Specific Threats

The threats to biodiversity in Pennsylvania have many sources, including:

Changing land use patterns lead to habitat and biodiversity as need for additional space for homes, schools, and businesses increases. Although Pennsylvania has not seen the same overall increases in population as other parts of the country, regions of the state, especially southeastern Pennsylvania, have been impacted adversely by urban sprawl and changing land use patterns.[8]

Deer represent a major threat to Pennsylvania's biodiversity because of their present over-abundance in many areas of the state. Deer were nearly extirpated in Pennsylvania in the 19th century due to overhunting. Establishment of more favorable habitat as forests were logged and fields cleared, enforcement of strict hunting regulations, and elimination of predators resulted in an increase in the population to an estimated 1.5 million today. Their increasing numbers and broad dietary preferences have reduced forest understory plants and retarded forest regeneration. Their feeding preferences also lead to secondary impacts. For example, deer find hay-scented fern unpalatable. In areas of high deer density, hay-scented fern dominates the forest floor vegetation, forming a nearly impenetrable layer that chokes out other herbs as well as young shrubs and tree seedlings.[8]

Invasive species are a large and growing threat to native biodiversity. Although native species, such as the elm spanworm and forest tent caterpillar, can become invasive, the greatest threats are from exotic plants and animals. While the introduction of non-native species into Pennsylvania began in the 1600s, the speed and frequency of modern travel has drastically increased opportunities for plants and animals to enter the state from other areas of the world. Most introduced species cause few problems but others, such as the zebra mussel and gypsy moth, can cause extensive damage to both native species and ecosystems. The threats posed by invasive species include displacement of native species, hybridization, and introduction of pathogens.

The problem of introduced and invasive species is especially prevalent in plant communities. More than 37 percent of the plant species currently found in Pennsylvania did not occur here at the time of European settlement. This

includes several invasive plants, such as purple loosestrife, Japanese honeysuckle, garlic mustard, Japanese knotweed, and autumn olive. Many of these, such as autumn olive, were planted as wildlife food and cover, and others, such Japanese honeysuckle, were introduced as ornamentals. [8]

Agriculture is Pennsylvania's primary industry and approximately one quarter of our land is farmland. Although important to our economy, working farms pose threats to biodiversity, primarily in the form of non-point source pollution from manures, fertilizers, and pesticides. Livestock allowed to enter areas near streams disrupt streambanks, thus increase erosion and sedimentation. Loss of streamside vegetation removed for crops or livestock also degrades stream systems by destabilizing banks and increasing water temperatures. Despite the potential threats from traditional agriculture, there is also concern over the loss of farmland and other open spaces to increasing development. [8]

Mining of coal and other minerals has occurred in Pennsylvania since the 18th century and has been a major contributor to the state's economic growth. At the same time, this industry has had a major negative impact on water quality, affecting more than 3,100 miles of streams. Many abandoned coal mines still leach a variety of chemicals. Aside from the direct impact of abandoned mine drainage (AMD), mining has further degraded stream channels by causing them to lose flow in areas where bedrock is broken. The loss of sport fishing due to AMD is estimated at $67 million per year. [8]

In addition, there are approximately 250,000 acres of unreclaimed mine lands, refuse banks, and old mine shafts in 45 of Pennsylvania's 67 counties. Because they are infertile, drought-prone, and subject to extreme temperatures, abandoned mine lands support sparse, unproductive ecosystems with a low diversity of plants and animals. An estimated $5 billion or more will be required to correct the problems of abandoned mines. [8]

Acid precipitation, or "acid rain," resulting from release of sulfur and nitrogen dioxides during the burning of fossil fuels, automobile exhaust, and other industrial processes, can occur as either wet (rain, snow, fog, or ice) or dry deposition. Progress is being made in this area. Although deposits were slightly more acidic in 2000 than in 1999, statistically significant trends of decreasing acidity are evident at all monitoring sites within the state from 1983 to 2000.[8]

Fire suppression has played a critical role in reducing the size of some specific habitats in Pennsylvania. For example, serpentine barrens, found only in small areas of southeastern Pennsylvania, depend on fire to maintain their unique plant and animal communities. Likewise, pitch-pine scrublands in mountainous regions of northern and central Pennsylvania depend on fire for regeneration. The oak- and chestnut-dominated forests, which covered about half of Pennsylvania at the time of European settlement, and still a major component of forests in the state, owe their existence to repeat past fires. [8]

Habitat loss and destruction

- Sprawl reduces biodiversity by destroying and fragmenting undisturbed natural areas that provide habitat for species.
- As habitat disappears, species populations decline in numbers or are entirely removed from the ecosystem.
- Fire suppression, flood control, and other efforts to alter natural processes for the convenience and economic benefit of sprawling communities can change the entire composition of ecosystems.
- Government agencies and nonprofit organizations are working on the conservation of large, landscape-scale areas, using strategies designed to link networks of habitat and effectively manage ecosystems as whole units.

Impacts of Sprawl on Habitat Conversion of Land Use

Uncontrolled development of natural areas is second only to agriculture as the most prevalent form of habitat loss threatening endangered species in the U.S. Developers bulldoze and fill wetlands, build office parks in prairies, and flood deserts to create golf courses, erasing essential habitat for a multitude of species and natural communities. Habitat conversion to urban, suburban, or agricultural development is responsible for 2 to 20 percent of species loss in the lower 48 states.

- 83 percent of 98 threatened or endangered plant species are threatened primarily by habitat destruction through human activity.

- 27 critically endangered ecosystems in the U.S. have lost more than 98 percent of the area they occupied at the time of European settlement.
- One million acres of open space, including parks, farms, and natural areas are lost to sprawl each year.
- Only 10 percent of all imperiled species populations live on lands protected from development.
- 50 percent of the continental U.S. no longer supports its original natural vegetation.
- Loss of habitat acreage leads to a decline in the abundance of a species, which reduces the genetic diversity within that species. This makes a species more susceptible to extinction, by making it less resistant to disease or catastrophic events. Habitat loss also reduces the potential for population maintenance or growth, as there is not sufficient area to support more individuals.
- The Florida panther has been reduced to a single population of 30 to 50 individuals; it has no other habitat into which the population can expand.
- Hot spots—concentrations of imperiled biodiversity—often coincide with areas of rapid development and growth. Hawaii, the San Francisco Bay Area, the southern California coast, and the Florida panhandle all harbor astonishing degrees of biodiversity, but they are also the focus of some of the most intensive development pressures in the nation.
- 150 years ago, San Francisco Bay supported grizzlies, salmon, elk, deer, pronghorn antelope, and cougar. Habitat loss is both quantitative—number of acres—and qualitative—degradation in the structure and composition of the habitat. Even areas of seemingly little human disturbance have had profound alterations since the beginning of European settlement. In many forested areas of the eastern U.S., total forest cover may now be greater than it was at the end of the 19th century, but the diversity of species within those forests has been dramatically changed. The trees, plants, and soils are likely to have less variety and to support different communities of species than were present in the original old-growth forest systems.

Fragmentation

Natural communities can be fragmented by roads, power lines, rural subdivisions, or pipelines. This fragmentation reduces biodiversity without directly destroying a large amount of habitat, for an area of contiguous forest will support many more species and individuals than the same total area divided into several small patches. Species that have large individual home ranges, those that prefer unbroken landscapes, and those that do not disperse among discontinuous habitat patches, are less able to hunt for food, find mates, and find appropriate nest or den sites in fragmented landscapes.

- Forest breeding birds of the eastern U.S. require a minimum of 7,400 acres of habitat to support viable populations.
- For many invertebrates and smaller vertebrates, a two-lane road presents an impassable barrier to movement between patches of habitat. Many species will not use habitat near a road or other disruption in the land, even though that area of habitat is otherwise equal in quality to areas more distant from the road. This limits the species' potential range to an area even smaller than that delineated by the road or the opening in the habitat.
- Habitat within 100 meters of the edge of a forest is poor quality habitat for songbirds living in forests, and they have reduced reproductive rates in these edge areas.

Fragmentation increases the proportion of edge to interior habitat patterns. The line where two habitat types meet is an edge, a specific niche exploited by several species which themselves can cause biodiversity loss. Brown-headed cowbirds, which live primarily on forest edges, are one source of biodiversity loss. These birds prefer to lay their eggs in other species' nests, leaving their hatchlings to be raised by those other species. Migratory songbirds, such as warblers and vireos, are often the unsuspecting hosts. Cowbird young are typically larger and hatch earlier than the nesting birds' eggs and thus out-compete the original hatchlings for food. In fragmented landscapes, birds' nests in the forest interior become more accessible to cowbirds, as the cowbirds follow edges further and further into the forest. Nest parasitism increases, and populations of the songbirds decline, often to the point of disappearing.

White-tailed deer also thrive in edge habitats, and their populations have exploded in recent years. These increased populations have a harmful effect on the diversity of forest plant species. The deer feed largely on seedlings, saplings, and herbaceous plants, eliminating regeneration of some tree species and decimating populations of susceptible wildflowers and herbs. This not only reduces forest floral diversity—trilliums are a deer favorite—it reduces habitat and food sources for many animal species, reducing diversity of fauna as well.

Alteration of Natural Processes
Flood Control and Fire Suppression

Flood control projects and fire suppression are among the top causes of habitat loss. As humans encroach on natural areas, we (understandably) seek to protect our homes and businesses from the floods and fires that are part of natural ecosystem processes. As a result, the Corps of Engineers has straightened and deepened rivers and built levees and dams, in order to control flooding (as well as to provide energy and facilitate transportation). These projects alter the hydrology and composition of aquatic and riverside communities, damaging or destroying habitat for species within those communities.

- Channelization and bank stabilization projects on the Missouri River have eliminated the river otter population from this waterway.
- The Willamette River in Oregon has lost 80% of riparian forests and shoreline habitats as a result of straightening and deepening the river channel. [4]

As a result of human activities such as water withdrawal, water diversion, and channelization many important aquatic resources have experienced alterations in their natural hydrologic conditions. These alterations include changes in the water table, water level, and flow rate.

Changes in natural water levels threaten biodiversity by reducing the ability of aquatic habitats to flush out nutrients and organic matter resulting in a decrease in primary productivity. In addition, lower water levels can also alter habitat condition causing the removal of certain aquatic species that require specific water heights to survive.

Alterations in water flow have also been known to adversely affect aquatic biodiversity. When water flow is reduced, it may decrease water levels, damaging spawning habitats of important fish species such as the lake sturgeon. Problems may also occur when water flow increases including the degradation of river and stream bottoms due to scouring, and the destruction of habitats relied upon by fish and other benthic organisms.

Water withdrawal for irrigation, mining excavations and land drainage, has caused problems in aquatic ecosystems including significant reductions in the water tables of many areas of the United States. By reducing the level of the water table, drought conditions have occurred in many wetland ecosystems. As a result, wetlands have shrunk in size and species unable to adjust to drought conditions have begun to die off at alarming rates.

The construction of channels and canals has also contributed to changes in the hydrology of aquatic ecosystems. Some of the impacts to aquatic ecosystems associated with channalization include:

- Alterations to natural water flow
- Increased erosion and/or sedimentation due to flow alterations
- Introduction of exotics species by the canal and increased shipping
- Increased pollution due to increased shipping and boating traffic [11]

By suppressing **wildfires**, the U.S. has dramatically altered the composition of its temperate forests and prairies. Prior to suppression, these ecosystems had frequent, low-intensity fires and a mosaic of diverse communities, supporting many different species. Fire suppression has reduced this diversity in two ways. First, a lack of frequent fires increases the "fuel" in the ecosystem, such as downed trees and low-lying shrubs and brush. This increased fuel means that any fires that do occur are likely to be more severe than in the past. Mature trees that could have survived a low-intensity fire succumb to

these extreme blazes. Second, a lack of fire results in a less complex landscape of communities. Longer intervals between fires allow the original mosaic of communities time to become more uniform in species composition, thus reducing biodiversity.

- As a result of suppressing the cyclical fires of the Florida panhandle, 98% of the longleaf pine forests there have disappeared.
- Lack of fire on Midwestern prairies and savannas has resulted in the loss of many of the native species of those communities.

Streams and Wetlands

Our nation's network of rivers, lakes, and streams originates from a myriad of small streams and wetlands, many so small they do not appear on any map. Yet these headwater streams and wetlands exert critical influences on the character and quality of downstream waters. The natural processes that occur in such headwater systems benefit humans by mitigating flooding, maintaining water quality and quantity, recycling nutrients, and providing habitat for plants and animals.

Scientists often refer to the benefits humans receive from the natural functioning of ecosystems as **ecosystem services**. The special physical and biological characteristics of intact small streams and wetlands provide natural flood control, recharge groundwater, trap sediments and pollution from fertilizers, recycle nutrients, create and maintain biological diversity, and sustain the biological productivity of downstream rivers, lakes, and estuaries. These ecosystem services are provided by seasonal as well as perennial streams and wetlands. Even when such systems have no visible overland connections to the stream network small streams and wetlands are usually linked to the larger network through groundwater.

Small streams and wetlands offer an enormous array of habitats for plant, animal, and microbial life. Such small freshwater systems provide shelter, food, protection from predators, spawning sites and nursery areas, and travel corridors through the landscape. Many species depend on small streams and wetlands at some point in their life history. A recent literature review documents the significant contribution of headwater streams to biodiversity of entire river networks, showing that small headwater streams that do not appear on most maps support over 290 taxa, some of which are unique to headwaters. As an example, headwater streams are vital for maintaining many of America's fish species, including trout and salmon. Both perennial and seasonal streams and wetlands provide valuable habitat. Headwater streams and wetlands also provide a rich resource base that contributes to the productivity of both local food webs and those farther downstream. However, the unique and diverse biota of headwater systems is increasingly imperiled. Human-induced changes to such waters, including filling streams and wetlands, water pollution, and the introduction of invasive species can diminish the biological diversity of such small freshwater systems, thereby also affecting downstream rivers and streams.

Because small streams and wetlands are the source of the nation's fresh waters, changes that degrade these headwater systems affect streams, lakes, and rivers downstream. Land-use changes in the vicinity of small streams and wetlands can impair the natural functions of such headwater systems. Changes in surrounding vegetation, development that paves and hardens soil surfaces, and the total elimination of some small streams reduces the amount of rainwater, runoff, and snowmelt the stream network can absorb before flooding. The increased volume of water in small streams scours stream channels, changing them in a way that promotes further flooding. Such altered channels have bigger and more frequent floods. The altered channels are also less effective at recharging groundwater, trapping downstream lakes and rivers have poorer water quality, less reliable water flows, and less diverse aquatic life. Algal blooms and fish kills can become more common, causing problems for commercial and sport fisheries. Recreational uses may be compromised. In addition, the excess sediment can be costly, requiring additional dredging to clear navigational channels and harbors and increasing water filtration costs for municipalities and industry.

The natural processes that occur in small streams and wetlands provide Americans with a host of benefits, including flood control, adequate high quality water, and habitat for a variety of plants and animals. Scientific research shows that healthy headwater systems are critical to the healthy functioning

of downstream streams, rivers, lakes, and estuaries. To provide the ecosystem services that sustain the health of our nation's waters, the hydrological, geological, and biological characteristics of small streams and wetlands require protection.[18]

Laws and programs that protect water include: Clean Water Act, Pennsylvania's Clean Streams Law, and Dam Safety and Encroachment Act.

Historically, federal agencies, in their regulations, have interpreted the protections of the Clean Water Act to broadly cover waters of the United States, including many small streams and wetlands. Despite this, many of these ecosystems have been destroyed by agriculture, mining, development, and other human activities. [8]

In the Commonwealth, Pennsylvania's Clean Streams Law is the cornerstone of the state's aquatic protection programs and also provides some regulation of activities affecting terrestrial habitats. By law, every stream or waterbody in Pennsylvania has an assigned designated use as Warm Water Fishes, Trout Stocking Fishery, Cold Water Fishes, or Migratory Fishes. The Clean Streams Law further emphasizes the importance of clean, unpolluted waters through objectives to prevent further pollution as well as to reclaim and restore every polluted stream in Pennsylvania. Pennsylvania, like other states, is subject to the federal Clean Water Act, which requires that impaired waters and their sources of impairment be identified and plans developed to remove the impairment.[8]

Wetlands and waterways also are protected in Pennsylvania under the Dam Safety and Encroachments Act. The regulations provide special protection for:

- Exceptional value wetlands defined as habitat for threatened or endangered species or hydrologically connected to such habitat.
- Wetlands in or along the floodplain of exceptional value waters or wild and scenic rivers.
- Wetlands that support public drinking water supplies.
- Wetlands in state-designated natural areas or wilderness areas.

Drought

Drought produces a complex web of impacts that spans many sectors of the economy and reaches well beyond the area experiencing physical drought. This complexity exists because water is integral to our ability to produce goods and provide services.

Impacts are commonly referred to as direct or indirect. Reduced crop, rangeland, and forest productivity; increased fire hazard; reduced water levels; increased livestock and wildlife mortality rates; and damage to wildlife and fish habitat are a few examples of direct impacts. The consequences of these impacts illustrate indirect impacts. For example, a reduction in crop, rangeland, and forest productivity may result in reduced income for farmers and agribusiness, increased prices for food and timber, unemployment, reduced tax revenues because of reduced expenditures, increased crime, foreclosures on bank loans to farmers and businesses, migration, and disaster relief programs. Direct or primary impacts are usually biophysical. Conceptually speaking, the more removed the impact from the cause, the more complex the link to the cause. In fact, the web of impacts becomes so diffuse that it is very difficult to come up with financial estimates of damages. The impacts of drought can be categorized as economic, environmental, or social.

Not all impacts of drought are negative. Some agricultural producers outside the drought area or with surpluses benefit from higher prices, as do businesses that provide water-related services or alternatives to water-dependent services; these types of businesses were among the “winners” in the 1987–89 U.S. drought.

Many **economic impacts** occur in agriculture and related sectors, including forestry and fisheries, because of the reliance of these sectors on surface and subsurface water supplies. In addition to obvious losses in yields in both, crop and livestock production, drought is associated with increases in insect infestations, plant disease, and wind erosion. Droughts also bring increased problems with insects and diseases to forests and reduce growth. The incidence of forest and range fires increases substantially during extended droughts, which in turn places both human and wildlife populations at higher levels of risk.

Income loss is another indicator used in assessing the impacts of drought because so many sectors are affected. Reduced income for farmers has a ripple effect. Retailers and others who provide goods and services to farmers face reduced business. This leads to unemployment, increased credit risk for financial institutions, capital shortfalls, and loss of tax revenue for local, state, and federal government. Less discretionary income affects the recreation and tourism industries. Prices for food, energy, and other products increase as supplies are reduced. In some cases, local shortages of certain goods result in the need to import these goods from outside the stricken region. Reduced water supply impairs the navigability of rivers and results in increased transportation costs because products must be transported by rail or truck. Hydropower production may also be curtailed significantly.

Social impacts mainly involve public safety, health, conflicts between water users, reduced quality of life, and inequities in the distribution of impacts and disaster relief. Many of the impacts specified as economic and environmental have social components as well. Population out-migration is a significant problem in many countries, often stimulated by greater availability of food and water elsewhere. Migration is usually to urban areas within the stressed area or to regions outside the drought area; migration may even be to adjacent countries, creating refugee problems. However, when the drought has abated, these persons seldom return home, depriving rural areas of valuable human resources necessary for economic development. For the urban area to which they have immigrated, they place ever-increasing pressure on the social infrastructure, possibly leading to greater poverty and social unrest. The drought-prone northeast region of Brazil had a net loss of nearly 5.5 million people between 1950 and 1980. Although not all of this population shift was directly attributable to drought, it was a primary factor for many in their decision to relocate. This continues to be a significant problem in Brazil and many other drought-prone countries.

Drought represents one of the most important natural triggers for malnutrition and famine, a significant and widespread problem in many parts of Africa and in other countries as well. Deaths resulting from famine are sometimes mistakenly attributed to drought rather than to underlying causes such as war or civil strife. Numerous early warning systems have been established in Africa to monitor a wide range of physical and social variables that signal a trend toward food insecurity. The Southern Africa Development Community (SADC), for example, monitors the crop and food situation in the region and issues alerts during periods of impending crisis.[12-15]

Floods

While many communities and individuals across Pennsylvania continue to flounder in the wake of devastation wrought by recent flooding, the rushing streams and rivers are little more than an inconvenience for some populations accustomed to water in their homes – fish populations. And although it may be hard to imagine for those of us who witnessed the floodwaters’ power, in terms of catastrophes, finned creatures view recent events on a different scale. For fish it’s simply a matter of adjusting to go with the flow.

As Pennsylvania Fish and Boat Commission biologist Dick Snyder points out, a flood is a natural event and Mother Nature equips her charges to deal with that which comes their way. According to Snyder, high waters may alter aquatic habitat and place stress on fishes, but for the most part the effects are short-term. As the Commission’s Chief of the Division of

Fisheries Management, Snyder has witnessed plenty of streams spill over their banks and he has also seen fish populations adapt.

"To a fish, a flood feels much like walking up an alley during a strong windstorm feels to us. And fish react in pretty much the same manner we do; just like we'll duck into a doorway to get out of the wind, fish will seek out those areas where the force of the water isn't as great," said Snyder.

Though some fish may be permanently dislocated during a flood, most manage to take refuge. Areas of refuge can be as simple as a stream bottom where water moves more slowly. Rocks or logs also offer shelter. Additionally, calm eddies out of the torrent provide congregation points for fish to rest – even if the pools are located in areas where they wouldn't normally be found, such as over a road or in a pasture.

As floodwaters recede, fish will usually find their way back to the usual holding spots, though Snyder noted some may get stranded in puddles and sinkholes if waters recede quickly. Trout may actually benefit from the high water as spawning areas might be scoured clean of silt and sediment. Only time will tell of the impact on American shad returning four or five years from now as the 2004 year class was in the process of migrating to the ocean.

It appears that the floods of 2004 won't significantly impact the Commission's stocked trout programs either. Some Commission hatcheries did experience some flooding, most notably the Benner Spring State Fish Hatchery in Centre County. While fish inventory work is ongoing, initially it does not appear there will be any major changes to the trout stocking program.

What many anglers may notice are some physical changes to trout streams and other bodies of water. "Many streams and rivers have been physically altered during the course of the flood," Snyder pointed out.

"Gravel and rocks have been swept downstream. Stream banks have been washed away and silt has been redeposited in different locations. Some areas that may have been prime fish habitat before are now gone altogether. Other areas that weren't ideal before may have been scoured and look just great."

While it will be weeks or months before the experts tabulate a final price tag on disaster damages from water and mud, the bottom line for fisheries is less clear. Said Snyder: "Short of reading about it somewhere, a few years from now it will be nearly impossible for us to tell there was even a flood." But, what happens the rest of this fall and winter may also have a great impact on fish populations awaiting our enjoyment next spring and summer.[21]

Alterations in Ecosystem Composition

The structure and functioning of the world's ecosystems changed more rapidly in the second half of the twentieth century than over any comparable period in human history. Humans are fundamentally, and to a significant extent irreversibly, changing the diversity of life on Earth and most of these changes represent a loss of biodiversity. Most changes to ecosystems have been made to meet a dramatic growth in the demand for food, water, timber, fiber and fuel.

- More land was converted to cropland in the 30 years after 1950 than in the 150 years between 1700 and 1850 (C26). Cultivated systems - areas where at least 30% of the landscape is in croplands, shifting cultivation, confined livestock production or freshwater aquaculture - now cover one quarter of Earth's terrestrial surface.
- Roughly 20% of the world's coral reefs were lost and an additional 20% degraded in the last several decades of the twentieth century (C19).
- The amount of water impounded behind dams has quadrupled since 1960; reservoirs now hold three to six times as much water as natural rivers. Water withdrawals from rivers and lakes have doubled since 1960. Most water use (70% worldwide) is for agriculture.
- Since 1960, flows of reactive (biologically available) nitrogen in terrestrial ecosystems have doubled and flows of phosphorus have tripled.
- Since 1750, the atmospheric concentration of carbon dioxide has increased by about 32% (from about 280 ppm to 376 ppm in 2003).

In the aggregate, and for most countries, changes made to the world's ecosystems in recent decades have provided substantial benefits. Many of the most significant changes to ecosystems have been essential to meet growing needs for food and water. These have helped to reduce the proportion of malnourished people and improve human health. However, these gains have been achieved at growing costs in the form of the degradation of many ecosystem services; increased risks of large, non-linear changes in ecosystems; exacerbation of poverty for some; and growing inequities and disparities across groups of people.

Human well-being is affected by changes in the composition, functioning and flow of ecosystem services. Management of an ecosystem to achieve a particular goal (such as food, timber production or flood control) generally results in changes to other ecosystem services. These changes are not always taken into account in planning, but they sometimes have significant impacts on human health.

Poor populations are more vulnerable to adverse health effects from both local and global environmental changes. Richer populations exert disproportionate pressure on global ecosystems but are less vulnerable. At present, major inequalities exist in access to ecosystem services. The status, or state, of these services is interlinked strongly with other components and determinants of poverty such as income, health and security. At the local level, poverty and the lack of access to clean, sustainable and efficient means for extracting ecosystem services can lead to local environmental degradation, with associated health risks. Also, poorer populations often live in environments that are more prone to infectious and other diseases, and have fewer resources for prevention and treatment. Richer populations have reduced health vulnerability to ecosystem degradation, partly because they are able to import resources from, and displace health risks to, other location.

Many of the people and places affected adversely by ecosystem changes and declining ecosystem services are highly vulnerable and ill-equipped to cope with further losses. Human alterations of ecosystems and their services shape the threats to which people and places are exposed and their vulnerability to those threats. The same alterations of environment can have very different consequences, with reference to the differential vulnerability of the dependent social and ecological systems. For example, disease emergence and re-emergence due to altered ecosystems can occur in both rich and poor countries, and on any continent. Nonetheless, people in the tropics are more likely to be affected in the future due to their greater exposure to such diseases and the greater scarcity of resources to cope with such ecosystem alterations and disease outbreaks in such regions. Highly vulnerable groups include those whose needs for ecosystem services already exceed the supply, such as people lacking adequate safe water supplies or living in areas with declining agricultural production (including a number of regions in Africa).

Vulnerability has increased as a result of the growth of populations in living ecosystems that are at greater risk from extreme weather or natural disasters, e.g. populations in low-lying coastal areas at risk of flooding, and populations in dry land ecosystems at risk of drought. Partly as a result of this, the number of natural disaster victims requiring international assistance has quadrupled over the past four decades. Finally, vulnerability is increased if either social or ecological resilience is diminished, e.g. through the loss of drought-resistant crop varieties; loss of farming expertise; or loss of institutional capacity to provide environmental management and health services that help protect local populations.[20]

Introduction of Non-native (exotic) Species

There are many ways in which the introduction of non-native or exotic species negatively affects our environment and the diversity of life on our planet. The statistics are startling and more attention must be paid to the problem and devising a solution before the cost is more than we can bear.

Compared to other threats to biodiversity, invasive introduced species rank second only to habitat destruction, such as forest clearing. Of all 1,880 imperiled species in the United States, 49% are endangered because of introduced species alone or because of their impact combined with other forces. In fact, introduced species are a greater threat to native biodiversity than pollution, harvest, and disease combined. Further, through damage to agriculture, forestry, fisheries, and other human enterprises, introduced species inflict an enormous economic cost, estimated at $137 billion per year to the U.S. economy alone.

Of course, some introduced species (such as most of our food crops and pets) are beneficial. However, others are very damaging.

The greatest impact is caused by introduced species that change an entire habitat, because many native species thrive only in a particular habitat. When the Asian chestnut blight fungus virtually eliminated American chestnut from over 180 million acres of eastern United States forests in the first half of the 20th century, it was a disaster for many animals that were highly adapted to live in forests dominated by this tree species. For example, ten moth species that could live only on chestnut trees became extinct.

Similarly, the Australian paperbark tree has replaced native plants, such as sawgrass, over 400,000 acres of south Florida, because it has a combination of traits (for example, spongy outer bark and flammable leaves and litter) that increase fire frequency and intensity. Many birds and mammals adapted and the native plant community declined in abundance as paperbark spread.

In similar fashion, aquatic plants such as South American water hyacinth in Texas and Louisiana and marine algae such as Australian Caulerpa in the Mediterranean Sea changed vast expanses of habitat by replacing formerly dominant native plants.

The zebra mussel, accidentally brought to the United States from southern Russia, transforms aquatic habitats by filtering prodigious amounts of water (thereby lowering densities of planktonic organisms) and settling in dense masses over vast areas. At least thirty freshwater mussel species are threatened with extinction by the zebra mussel.

Other invaders, though they do not change a habitat, endanger single species or even entire groups of them in various ways:

- The predatory brown tree snake, introduced in cargo from the Admiralty Islands, has eliminated ten of the eleven native bird species from the forests of Guam.
- The Nile perch, a voracious predator introduced to Lake Victoria as a food fish, has already extinguished over one hundred species of native cichlid fish there.
- A parasite can be similarly devastating. The sea lamprey reached the Great Lakes through a series of canals and, in combination with overfishing, led to the extinction of three endemic fishes.
- The European parasite that causes whirling disease in fishes, introduced to rainbow trout in a hatchery in Pennsylvania, has now spread to many states and devastated the rainbow trout sport fishery in Montana and Colorado.
- Herbivores can wreak great damage. The first sailors to land on the remote Atlantic island of St. Helena in the 16th century introduced goats, which quickly extinguished over half the endemic plant species.

Some impacts of invaders are subtle but nonetheless destructive to native species:

- North American gray squirrels are driving native red squirrels to extinction in Great Britain and Italy by foraging for nuts more efficiently than the native species. Such competition for resources is not easy to observe, but the end result is the loss of a native species.
- Hybridization, or cross-breeding, of introduced species with natives is an even subtler impact (no lineage goes extinct), but it is insidious because it leads gradually to the extinction of many native species, as their gene pools inevitably evolve to become those of the invader. Introduced mallards, for instance, are driving the native Hawaiian duck to a sort of genetic extinction by breeding with them.
- Of 26 animal species that have gone extinct since being listed under the Endangered Species Act, at least three were wholly or partly lost because of hybridization with invaders. One was a fish native to Texas, eliminated by hybridization with introduced mosquito fish.
- Rainbow trout introduced widely in the United States as game fish are hybridizing with five species listed under the Endangered Species Act, such as the Gila trout and Apache trout.
- The endangered, endemic Hawaiian duck is being lost to hybridization with North American mallards introduced for hunting. The rarest European duck (the white-headed duck) is threatened by hybridization with the North American ruddy duck, which was originally kept as an amenity in a British game park. The ruddy duck escaped, crossed the English Channel, and spread to Spain, the last stronghold of the white-headed duck.

Often invaders interact with one another to generate a problem where either species alone would be harmless. For example, ornamental fig trees in the Miami area for over a century stayed where planted, in people's yards, because they were sterile. Each fig species requires a particular wasp to pollinate it, and the wasps were absent. About fifteen years ago, the pollinating wasps for three fig species arrived independently in the region, and now these fig species are reproducing. At least one has become invasive, with seedlings and saplings being found many miles from any planted figs. More cases of this phenomenon, termed "invasion meltdown," are likely to arise as more species are introduced and have the opportunity to interact with each other.

Warding off the intruder

Keeping potentially damaging invaders out is the most cost-effective way to deal with introduced species. Targeting common pathways by which invaders reach our shores can slow or stop their entry. Ship ballast water, wooden packing material, and horticultural plants are three prominent pathways for invasion that could all be monitored or treated more rigorously.

A species that is introduced despite precautions can sometimes be eradicated, especially if discovered quickly. In the United States, a Giant African snail population was eliminated by a long campaign in Florida and a federal-state cooperative effort is currently underway in California to attempt to eradicate the recently discovered Caulerpa alga invasion. Even if eradication fails, several technologies often can control invasive species at acceptably low levels. No method is a magic bullet, each can have drawbacks if misused, and each has failed when used against certain invaders, but each also has successes to its credit.

Biological control entails introducing a natural enemy usually from the native range of the introduced pest. For example, prickly pear cactus from the Americas is well controlled on hundreds of thousands of square miles of Australian rangeland by caterpillars of a moth introduced from South America. A disadvantage of biological control is that some agents attack nontarget species, and it is very difficult to remove a troublesome introduced natural enemy once it is established.

Chemical control involves using a pesticide, such as an herbicide or insecticide. Although chemicals can effectively control some species (such as water hyacinth in Florida), they may have nontarget impacts, they are often expensive, and pests can evolve resistance to them.

In mechanical control, hand pulling or various kinds of machinery are employed. For example, volunteer convict labor is used in Florida to cut paperbark trees and in Kentucky to rip out Eurasian musk thistle. However, some invaders cannot be easily found for mechanical removal or occupy a habitat (for example, the marine benthos) that is not readily accessible.

The newest technology for managing invaders is ecosystem management, in which the entire ecosystem is subject to a regular treatment (such as a simulated natural fire regime) that tends to favor adapted native species over most exotic invaders. Because it is so new, the specific ways in which ecosystem management can be employed must be determined in each type of habitat.

Addressing the problem

International cooperation and management is the solution.

The numbers of introduced species are growing in the United States and elsewhere because of increased trade and travel, but the situation is not hopeless.

Internationally, the Rio Convention of Biological Diversity (1992) recognized the threat and called for action to limit it. A Global Invasive Species Program, formed by the United Nations and other international organizations, is beginning to answer this call with a series of programs designed to deal with particular sorts of introduced species.

In the United States, a Presidential Executive Order in 1999 called for the formation of a Federal Invasive Species Council to render the federal response to introduced species more effective, and to foster cooperation among federal agencies, state agencies, and other stakeholders such as conservation organizations and private landowners. The Council has formulated a Management Plan that includes many activities to slow the influx of invasive introduced species and to deal with them more effectively once they are present.

If all these policies (or global measures) and weapons are used in the battle against invaders, there is every reason to think that most native species and ecosystems can be protected against this threat. If our interest or support falters, the current wave of invaders will surely become a flood, leading to massive habitat change and extinction as much of the earth undergoes a massive biotic homogenization. 5

Over-Exploitation

Over-exploitation in some cases lead to exhaustion, particularly by excessive forestry, fishing and hunting. This over-exploitation may be explained in part by human overpopulation in some areas of the planet, ever-increasing world demand for these resources and the development of international trade.

Industrial-scale logging, for wood products and timber, destroys or fragments millions of acres of forests each year, along with the habitat they provide to many uniquely adapted species. Over-harvesting of fisheries has driven several fish species to the brink of extinction and reduced the overall diversity of marine life.[7] For example, Lake Erie trout populations have also suffered as a result of overfishing and environmental stress and over harvesting was one of the key factors contributing to the former decline in the Chesapeake Bay native oyster population.[9] Over-hunting and illegal trade in endangered species are a prime threat to their survival. This occurs even in the well-developed countries such as the U.S. For example, box turtles in the U.S are illegally collected and exported as pets, and, they die in the tens of thousands each year. These species are very slow to reproduce, and, in some populations, poaching has resulted in too few hatchlings surviving to offset adult mortality.[7]

To the moment, a dozen of species that were most popular fishes during the hundreds of years became rare and endangered species. Like god-fish, in many areas herring, wild salmon and few more species now have almost no economic value in the North Atlantic seas. Even if there are still some quotas for fishery of these species, the volume of quotas decreased annually.[7]

Not only fishes, but also invertebrates and macro algae are under pressure of human beings. In many countries inhabitants collect invertebrates along the tidal. In vicinities of cities and settlements the tidal communities could be really "eaten away".[7]

Pollution

Oceans have historically been the dumping grounds for the wastes from society. Fortunately, this view has changed and regulations have become much more stringent, but the effects of the past still linger. Pollution has been very damaging to aquatic ecosystems, and may consist of agricultural, urban, and industrial wastes containing contaminants such as sewage, fertilizer, and heavy metals that have proven to be very damaging to aquatic habitats and species.

Many of the pollutants entering aquatic ecosystems (e.g., mercury lead, pesticides, and herbicides) are very toxic to living organisms. They can lower reproductive success, prevent proper growth and development, and even cause death. The organisms that are most directly and adversely affected by toxic pollutants consist of larvae, eggs, and other organisms that live at the surface or near the bottom of aquatic habitats where pollutants tend to settle. Filter feeders (e.g., clams, and mussels) and other organisms higher up in the food chain (e.g., swordfish, tuna) are also affected by the presence of toxicants. Filter feeders and predatory fin-fish are not directly affected by the presence of toxic chemicals in the water column or sediments. Instead they bioconcentrate and bioaccumulate the toxicants. For example, humans, animals, and birds have been known to suffer from mercury poisoning, lead poisoning, and other neurological diseases from eating fish and shellfish that are contaminated with high levels accumulated toxicants.

In addition to toxic pollutants, increased nutrients, especially nitrogen and phosphorus, from city sewage and fertilizers from agricultural areas (e.g. animal feed lots) have also proven to be very damaging to aquatic ecosystems. Certain levels of these nutrients are known to cause harmful algal blooms in both freshwater and marine habitats. In turn, algal blooms impact aquatic biodiversity by affecting water clarity, depleting oxygen levels, and crowding out organisms within an ecosystem. In some instances algal blooms have produced neuro-

toxins that have led to species die-offs and illnesses such as paralytic shellfish poisoning.
Other pollutants affecting biodiversity in aquatic ecosystems are solid pollutants like plastic bags, plastic rings, abandoned fishing gear, and other man-made materials that result from garbage dumped from shore and ships. Trash and debris of this nature floating in aquatic environments, have been known to entangle and even kill marine mammals and birds. Animals such as sea turtles have often died through ingesting bits of plastic and other discarded materials. In addition, abandoned fishing gear such as lobster pots and nets are self-baiting and will continue to catch and kill fish and other organisms for years after the gear has been discarded or lost.

Tanker accidents have contributed to oil pollution in marine environments. The ecological consequences of these oil spills in marine systems have been quite severe. It is well documented that oil has a lethal effect on eggs and larvae, seabirds, and any many other surface dwellers (including larvae of commercially important species) through asphyxiation and poisoning effects. Oil exposure can also cause the loss of fur and feathers among mammals and birds resulting in hypothermia and can also inhibit them from eating, which can also be fatal. [10]

Pesticides

Use of pesticides can have unintended effects on the environment. Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, including non-target species, air, water, bottom sediments, and food. Pesticide contaminates land and water when it escapes from production sites and storage tanks, when it runs off from fields, when it is discarded, when it is sprayed aerially, and when it is sprayed into water to kill algae. The amount of pesticide that migrates from the intended application area is influenced by the particular chemical's properties: its tendency for binding to soil, its vapor pressure, its water solubility, and its resistance to being broken down over time. Factors in the soil, such as its texture, its ability to retain water, and the amount of organic matter contained in it, also affect the amount of pesticide that will leave the area. Some pesticides contribute to global warming and the depletion of the ozone layer.

Air

Pesticides can contribute to air pollution. Pesticide drift occurs when pesticides suspended in the air as particles are carried by wind to other areas, potentially contaminating them. Pesticides that are applied to crops can volatilize and may be blown by winds into nearby areas, potentially posing a threat to wildlife. Also, droplets of sprayed pesticides or particles from pesticides applied as dusts may travel on the wind to other areas, or pesticides may adhere to particles that blow in the wind, such as dust particles. Ground spraying produces less pesticide drift than aerial spraying does. Farmers can employ a buffer zone around their crop, consisting of empty land or non-crop plants such as evergreen trees to serve as windbreaks and absorb the pesticides, preventing drift into other areas.

Pesticides that are sprayed onto fields and used to fumigate soil can give off chemicals called volatile organic compounds, which can react with other chemicals and form a pollutant called ozone, accounting for an estimated 6% of the total ozone production.

Water

In the United States, pesticides were found to pollute every stream and over 90% of wells sampled in a study by the US Geological Survey. Pesticide residues have also been found in rain and groundwater.

Pesticide impacts on aquatic systems are often studied using a hydrology transport model to study movement and fate of chemicals in rivers and streams. As early as the 1970s quantitative analysis of pesticide runoff was conducted in order to predict amounts of pesticide that would reach surface waters.

There are four major routes through which pesticides reach the water: it may drift outside of the intended area when it is sprayed, it may percolate, or leach, through the soil, it may be carried to the water as runoff, or it may be spilled, for example accidentally or through neglect. They may also be carried to water by eroding soil. Factors that affect a pesticide's ability to contaminate water include its water solubility, the distance from an application site to a body of water, weather, soil type, presence of a growing crop, and the method used to apply the chemical. Maximum limits of allowable concentrations

for individual pesticides in public bodies of water are set by the Environmental Protection Agency in the US.

Soil
Many of the chemicals used in pesticides are persistent soil contaminants, whose impact may endure for decades and adversely affect soil conservation.

The use of pesticides decreases the general biodiversity in the soil. Not using the chemicals results in higher soil quality, with the additional effect that more organic matter in the soil allows for higher water retention. This helps increase yields for farms in drought years, when organic farms have had yields 20-40% higher than their conventional counterparts. A smaller content of organic matter in the soil increases the amount of pesticide that will leave the area of application, because organic matter binds to and helps break down pesticides.

Plants
Nitrogen fixation, which is required for the growth of higher plants, is hindered by pesticides in soil. The insecticides DDT, methyl parathion, and especially pentachlorophenol have been shown to interfere with legume-rhizobium chemical signaling. Reduction of this symbiotic chemical signaling results in reduced nitrogen fixation and thus reduced crop yields. Root nodule formation in these plants saves the world economy $10 billion in synthetic nitrogen fertilizer every year.

Pesticides can kill bees and are strongly implicated in pollinator decline, the loss of species that pollinate plants, including through the mechanism of Colony Collapse Disorder, in which worker bees from a beehive or Western honey bee colony abruptly disappear. Application of pesticides to crops that are in bloom can kill honeybees, which act as pollinators. The USDA and USFWS estimate that US farmers lose at least $200 million a year from reduced crop pollination because pesticides applied to fields eliminate about a fifth of honeybee colonies in the US and harm an additional 15%.

Persistent organic pollutants
Persistent organic pollutants (POPs) are compounds that resist degradation and thus remain in the environment for years. Some pesticides, including aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hesachlorobenzene, mires, and toxaphene, are considered POPs. POPs have the ability to volatilize and travel great distances through the atmosphere to become deposited in remote regions. The chemicals also have the ability to bioaccumulate and biomagnify, and can bioconcentrate (i.e. become more concentrated) up to 70,000 times their original concentrations. POPs may continue to poison non-target organisms in the environment and increase risk to humans by disruption in the endocrine, reproductive, and immune systems; cancer; neurobehavioral disorders, infertility and mutagenic effects, although very little is currently known about these chronic effects. Some POPs have been banned, while others continue to be used.

Animals

Animals may be poisoned by pesticide residues that remain on food after spraying, for example when wild animals enter sprayed fields or nearby areas shortly after spraying.

Widespread application of pesticides can eliminate food sources that certain types of animals need, causing the animals to relocate, change their diet, or starve. Poisoning from pesticides can travel up the food chain; for example, birds can be harmed when they eat insects and worms that have consumed pesticides. Some pesticides can bioaccumulate, or build up to toxic levels in the bodies of organisms that consume them over time, a phenomenon that impacts species high on the food chain especially hard.

The USDA and USFWS estimate that about 20% of the endangered and threatened species in the U.S. are jeopardized by use of pesticides.

Birds
Birds are common examples of non-target organisms that are impacted by pesticide use. Rachel Carson's landmark book Silent Spring dealt with the topic of loss of bird species due to bioaccumulation of pesticides in their tissues. There is evidence that birds are continuing to be harmed by pesticide use. In the farmland of Britain, populations of ten different species of birds have declined by 10 million breeding individuals between 1979 and 1999, a phenomenon thought to have resulted from loss of plant and invertebrate species on which the birds feed. Throughout Europe, 116 species of birds are now threatened. Reductions in bird populations have been found to be associated with times and areas in

which pesticides are used. In another example, some types of fungicides used in peanut farming are only slightly toxic to birds and mammals, but may kill off earthworms, which can in turn reduce populations of the birds and mammals that feed on them.
Some pesticides come in granular form, and birds and other wildlife may eat the granules, mistaking them for grains of food. A few granules of a pesticide are enough to kill a small bird.

The herbicide paraquat, when sprayed onto bird eggs, causes growth abnormalities in embryos and reduces the number of chicks that hatch successfully, but most herbicides do not directly cause much harm to birds. Herbicides may endanger bird populations by reducing their habitat.

The USDA and USFWS estimate that over 67 million birds are killed by pesticides each year in the U.S.

Aquatic life
Fish and other aquatic biota may be harmed by pesticide-contaminated water. Pesticide surface runoff into rivers and streams can be highly lethal to aquatic life, sometimes killing all the fish in a particular stream. Pesticide-related fish kills are frequently unreported and likely underestimated.

Application of herbicides to bodies of water can cause fish kills when the dead plants rot and use up the water's oxygen, suffocating the fish. Some herbicides, such as copper sulfite, that are applied to water to kill plants are toxic to fish and other water animals at concentrations similar to those used to kill the plants. Repeated exposure to sub-lethal doses of some pesticides can cause physiological and behavioral changes in fish that reduce populations, such as abandonment of nests and broods, decreased immunity to disease, and increased failure to avoid predators.

Application of herbicides to bodies of water can kill off plants on which fish depend for their habitat.

Pesticides can accumulate in bodies of water to levels that kill off zooplankton, the main source of food for young fish. Pesticides can kill off the insects on which some fish feed, causing the fish to travel farther in search of food and exposing them to greater risk from predators.

The USDA and USFWS estimate that between 6 and 14 million fish are killed by pesticides each year in the U.S.

The faster a given pesticide breaks down in the environment, the less threat it poses to aquatic life. Insecticides are more toxic to aquatic life than herbicides and fungicides.

Amphibians
Some scientists believe that certain common pesticides already exist at levels capable of killing amphibians in California. They warn that the breakdown products of these pesticides can be 10 to 100 times more toxic to amphibians than the original pesticides. Direct contact of sprays of some pesticides (either by drift from nearby applications or accidental or deliberate sprays) can be highly lethal to amphibians.

U.S. scientists have found that some pesticides used in farming disrupt the nervous systems of frogs, and that use of these pesticides is correlated with a decline in the population of frogs in the Sierra Nevada. In the past several decades, decline in amphibian populations has been occurring all over the world, for unexplained reasons which are thought to be varied but of which pesticides may be a part. Being downwind from agricultural land on which pesticides are used has been linked to the decline in population of threatened frog species in California.

Mixtures of multiple pesticides appear to have a cumulative toxic effect on frogs. Tadpoles from ponds with multiple pesticides present in the water take longer to metamorphose into frogs and are smaller when they do, decreasing their ability to catch prey and avoid predators.

In Minnesota, pesticide use has been causally linked to congenital deformities in frogs such as eye, mouth, and limb malformations. Researchers in California found that similar deformities in frogs in the U.S. and Canada may have been caused by breakdown products from pesticides which themselves did not pose a threat.

The herbicide atrazine has been shown to turn male frogs into hermaphrodites, decreasing their ability to reproduce.

Pesticide resistance

Pests may evolve to become resistant to pesticides. Many pests will initially be very susceptible to pesticides, but some with slight variations in their genetic makeup are resistant and therefore survive to reproduce. Through natural selection, the pests may eventually become very resistant to the pesticide.

Pest resistance to a pesticide is commonly managed through pesticide rotation, which involves alternating among pesticide classes with different modes of action to delay the onset of or mitigate existing pest resistance.

Tank mixing pesticides is the combination of two or more pesticides with different modes of action in order to improve individual pesticide application results and delay the onset of or mitigate existing pest resistance.

Pest rebound and secondary pest outbreaks

Non-target organisms, organisms that the pesticides are not intended to kill, can be severely impacted by use of the chemicals. In some cases, where a pest insect has some controls from a beneficial predator or parasite, an insecticide application can kill both pest and beneficial populations. A study comparing biological pest control and use of pyrethroid insecticide for diamondback moths, a major cabbage family insect pest, showed that the insecticide application created a rebounded pest population due to loss of insect predators, whereas the biocontrol did not show the same effect. Likewise, pesticides sprayed in an effort to control adult mosquitoes, may temporarily depress mosquito populations, however they may result in a larger population in the long run by damaging the natural controlling factors. This phenomenon, wherein the population of a pest species rebounds to equal or greater numbers than it had before pesticide use, is called pest resurgence and can be linked to elimination of predators and other natural enemies of the pest.

Loss of predator species can also lead to a related phenomenon called secondary pest outbreaks, an increase in problems from species which were not originally very damaging pests due to loss of their predators or parasites. An estimated third of the 300 most damaging insects in the US were originally secondary pests and only became a major problem after the use of pesticides. In both pest resurgence and secondary pest outbreaks, the natural enemies have been found to be more susceptible to the pesticides than the pests themselves, in some cases causing the pest population to be higher than it was before the use of pesticide.[16]

Global Climate Change

Air and water pollution do not respect national borders. Acid rain, which results when air pollutants mix with falling rain, is a good example. In the North American, industrial emissions from U.S. factories have caused acid rain to damage sugar maples in Canada, threatening future maple syrup production.

Carbon released from such human-induced activities as the burning of fossil fuels, forests, and other natural habitats is a major contributor to climate change. Tropical forest burning outside the U.S. has accounted for about 25% of all carbon released into the atmosphere over the past decade.

Rapid build-up of carbon-dioxide and other greenhouse gases in the Earth's atmosphere, combined inextricably with ozone depletion, is causing our climate to change.[17]

Global climate change poses risks to human health and to terrestrial and aquatic ecosystems. Important economic resources such as agriculture, forestry fisheries, and water resources also may be affected. Warmer temperatures, more severe droughts and floods, and sea level rise could have a wide range of impacts.

All these stresses can add to existing stresses on resources caused by other influences such as population growth, land-use changes, and pollution.[6]

Climate Change in Pennsylvania

Below are some of the potential impacts:

- By 2100 temperatures in Pennsylvania could increase by about 4˚F (with a range of 2-9˚F), slightly less in summer and fall, and slightly more in winter and spring. Higher temperatures and increased frequency of heat waves may increase the number of heat-related deaths and incidence of heat-related illnesses.
- Precipitation is estimated to increase by about 10% in spring, by about 20% in winter and summer, and by as much as 50% in the fall. Although it is not clear how severe storms would change, an increase in the frequency and intensity of summer thunderstorms is possible.
- A preliminary modeling study of the Midwest, which included the area around Pittsburgh, found that a 4˚F warming, with no other change in weather or emissions, could increase concentrations of ozone, a major component of smog, by as much as 8%. Currently, ground-level ozone concentrations exceed national ozone health standards in several areas throughout the state, with the Philadelphia area classified as a "severe" non-attainment area for ozone. Ground-level ozone has been shown to aggravate respiratory illnesses such as asthma, reduce existing lung function, and induce respiratory inflammation.
- Pennsylvania's Susquehanna River drains much of the eastern two-thirds of the state, and the Allegheny and the upper Ohio rivers drain most of the western third. A warmer climate would lead to earlier spring snowmelt, and could result in higher streamflows in winter and spring and lower streamflows in summer and fall. However, changes in rainfall also could have significant effects on streamflow and runoff and, if precipitation increases in winter or summer this could offset losses from increased evaporation, but also could lead to increased flood risk. Some of the most intense flooding on record in the United States has occurred in Pennsylvania.
- In Pennsylvania, agriculture is a $3.8 billion annual industry, two-thirds of which comes from livestock, most of which is dairy. About 6% of the crop acreage is irrigated. The major crops in the state are corn and hay. Climate change could change crop yields very little or by as much as 39%, leading to changes in acres farmed and production. For example, hay yields could rise while production falls because of a decrease in hay acres farmed.

- With changes in climate, the extent of forested areas in Pennsylvania could change little or decline by as much as 15-25%. However, the types of trees dominating Pennsylvania forests and woodlands are likely to change. The maple, beech, and birch forests found in northern Pennsylvania would retreat northward. Forest areas would become dominated by oak, ash, hickory, and pine, and the brilliant autumn foliage associated with maples would be diminished. As a result, the character of forests in Pennsylvania may change.
- Climate change could adversely affect ecosystems such as the Erie National Wildlife Refuge and French Creek, which flows for 117 miles through northwestern Pennsylvania. This area provides habitat for approximately 70 species of fish and 25 species of freshwater mussels. Many of the aquatic species in French Creek (for example, the clubshell mussel) are already endangered. The refuge system also provides important habitat for birds, including the threatened bald eagle. [6]

WHAT IS BEING DONE/WHAT CAN BE DONE

Ecosystem Conservation

Biodiversity conservation will depend on stemming the loss of habitat from development, fragmentation, and degradation. Isolated patches of intact habitat will not be sufficient to preserve biodiversity, so conservation strategies need to be implemented at the ecosystem level. A handful of public agencies and many nonprofit organizations are working on conservation of landscape-scale areas, using strategies designed to link networks of conservation areas and effectively manage ecosystems.

Best Management Practices (BMP)

The advancement of BMPs from addressing only specific environmental degradation to embracing habitat restoration and biodiversity issues is exemplified by the Pennsylvania Forestry BMPs developed by the Cooperative Extension Service at Pennsylvania State University in cooperation with the forest products industry, forest landowners, and other groups. Initially, forestry BMPs were directed only at reducing water pollution from erosion and sedimentation. They eventually were expanded to address both water quality and wetlands protection issues because of their impact on wildlife habitat and threatened and endangered species. Currently, many forestry management practices in Pennsylvania directly integrate biodiversity conservation with measures for increased yield of timber and healthy forests.[8]

When best management practices and land protection efforts fail at conserving biodiversity, the remaining option is to attempt to restore or reintroduce what has been lost. Restoration and reintroduction projects have been somewhat successful in counteracting the loss of species and habitats in Pennsylvania. These projects have taken many forms, ranging from wetland restoration and fire management to replanting native grasslands and translocating animals to their former ranges.[8]

Habitat Restoration

Concerted efforts have been made, especially in the 1990s, to restore or repair habitat damage. Most efforts in Pennsylvania have focused on aquatic areas rather than terrestrial ones, with the exception of sites disturbed by former industrial uses (brownfields).[8]

- **Wetland restoration** and creation of new wetlands have been advanced by recognition of the ecological services that wetlands provide. While replacing wetlands on an equal area basis is the emphasis of most mitigation projects, there is less concern for replacing ecological functions. In addition, many mitigated wetlands are being replaced with dissimilar wetland types. For instance, while the greatest loss of wetlands has been of the scrub-shrub type, most restored wetlands are open water types, which have lower ecological value.[8]

  Despite initial optimism that created wetlands would perform the same functions as native wetlands, recent evidence suggests this is not the case. Poor wetland design, inability to establish vegetation, and the influx of invasive species are some of the reasons that wetland mitigation projects fail. In spite of such evidence, some argue that created wetlands have not been given sufficient time to achieve all of their potential ecological functions.[8]

- **Terrestrial habitat restorations** in Pennsylvania are attempting to establish grassland habitats on former agricultural lands, abandoned mine sites, and other disturbed areas. Abandoned mine sites, in particular, offer opportunities for creating grasslands that can attract birds and other species that prefer these habitats. Raptors such as northern harrier and American kestrel, for example, use reclaimed lands in western Pennsylvania.[8]

Reintroductions

Throughout the last century, several species of animals ranging from river otters to elk have been reintroduced to Pennsylvania with mixed success. For some projects, however, many additional years are needed before success can be assessed. While the definition of success varies, progress has been made especially with larger mammals and birds. Nevertheless, the difficulties and especially the high costs of many reintroduction efforts are a reminder that replacement is not a substitute for biodiversity conservation. The majority of active reintroductions in Pennsylvania involve larger mammals, birds, or fish. These include game species such as elk, turkey, and American shad as well as raptors such as bald eagle and peregrine falcon.

In many cases, animal species have been able to naturally recolonize in restored habitats, but often additional measures such as translocation of animals from other regions is necessary.[8] And some reintroductions, such as the peregrine falcon, have had a great deal of human involvement.[8]

- **American Shad.** Until dams impeded their travel, American shad returned each year to the headwaters of the Susquehanna River in New York. Hundreds of thousands of fish migrated annually through Pennsylvania and were an important food source for settlers and American Indians. Although populations of shad survived below the last canal dam at Columbia, water pollution, failed fish passages, and overharvesting led to their decline.[8]
- **River Otter.** River otters declined in Pennsylvania in the 1800s and early 1900s due to habitat loss and unregulated hunting. By the 1950s, populations were limited to the Pocono Mountains. In 1982, river otters captured in New York and New Hampshire were released in Pennsylvania. In the 1990s, 82 river otters were reintroduced to five stream and river systems, primarily in northern counties that are densely forested and sparsely populated. A 1994 survey located otters in at least 47 counties. Of the 25 established populations in the state, nine are considered to be expanding, 12 stable, and four declining or unknown. Water quality problems due to pollution from sources such as abandoned mine drainage are the greatest impediment to river otter reintroduction. Accidental trapping is also a cause of mortality, with 87 otters accidentally killed between 1989 and 1994.[8]

- **Wild Turkey.** Probably one of Pennsylvania's greatest reintroduction success stories is the wild turkey. Wild turkeys were eliminated in most of the eastern United States, including Pennsylvania, by the late 1800s due to overhunting and habitat loss by logging. Attempts were made throughout the 20th century to reintroduce wild turkey in Pennsylvania. Ultimately, a trap and transfer program begun in 1956, coupled with the return of preferred habitat and expansion of the remaining turkeys' range, led to their successful comeback. The population of wild turkeys was estimated at more than 400,000 birds in 2000 and continues to increase each year. Today, wild turkeys are found in every county in Pennsylvania, and are regularly seen in Pittsburgh and the Philadelphia suburbs.[8]

Government Initiatives

The U.S. Fish and Wildlife Service has adopted as its mission "the effective conservation of natural biological diversity through perpetuation of dynamic, healthy ecosystems." This new approach is being used to plan for national wildlife refuges as links in a continuous landscape, rather than as discrete, isolated units.

Many states have policies and programs that promote open space preservation as well as local planning efforts that preserve natural communities. These initiatives foster urban renewal, establish zones for open space, and set up funds for the protection of existing natural areas, all of which result in less habitat lost to development.

- Maryland's Rural Legacy Program will spend $71.3 million over four years to create links among protected areas, establishing networks of wild lands.
- In 2000, California voters passed two bonds of more than $4 billion to add ecologically significant properties to state parks and to restore and protect critical watersheds and rivers.
- In 1999, voters passed 90% of 102 ballot questions on protection of open space, generating $1.8 billion in funds for open space preservation.

Following Oregon's adoption of statewide planning codes in 1973, many other states have inaugurated smart growth legislation to curb sprawl. These acts and laws use urban growth boundaries, alternative transportation, and coordinated local planning to integrate open space preservation into all levels of government. In combination with increased spending on transportation alternatives, these policies work to renew the economic vitality of cities, drawing businesses and people back downtown and reducing pressure on undeveloped open space.

Conservation Efforts

Today, there are more than 1,210 local land trusts working to protect open space and wildlife habitat through direct land purchase or conservation easements. These land trusts, working in every state in the nation, have protected over 4.7 million acres of natural habitat from development.

- The Minnesota Land Trust has grown from a volunteer organization, focusing on Washington County in 1991, to a statewide operation with nine staff that has protected nearly 12,500 acres.
- The Montana Land Reliance holds conservation easements on over 26,500 acres in the Greater Yellowstone area, the world's largest intact temperate ecosystem. In addition, elsewhere in the state, it has protected approximately 360,000 acres with conservation easements.

The Nature Conservancy is designing conservation plans for 63 ecoregions in the continental U.S. These plans identify the species and natural communities within each ecoregion. A list of conservation targets is developed and long-term goals are set, both of which then guide the design of natural area preserves. Strategies for the conservation of these species and communities include land protection through acquisition and easements as well as partnerships with government agencies and private landowners.

Numerous other nonprofit organizations work to preserve remaining intact natural ecosystems and to reduce the rate and scale of development. Several conservation groups, such as the Wildlands Project, are now focusing their efforts on core protected areas that are connected by corridors. These corridors enable animals to pass through areas of more concentrated human use and development as they move between core areas. Corridors can be used to offset the effects of fragmentation on the movement of species, effectively enlarging their available habitat. Current projects involve protection and restoration of large-scale habitat in the American Southwest and in the Yellowstone-to-Yukon corridor along the northern Rocky Mountain chain.

- The Chesapeake Bay Foundation uses advocacy, restoration, and environmental education to protect and restore the health of the Bay. The group has been in existence since 1967 and has been instrumental in creating a coalition of government and business leaders from the six states in the watershed of the Bay.
- The network of "1000 Friends" groups in over two dozen states and cities uses education and advocacy to promote smart growth techniques to curb sprawl and rebuild cities.
- The Wilderness Society, the Sierra Club, and dozens of state and regional coalitions work to protect wilderness areas—areas that provide core habitat for many species. [4]
- Pennsylvania's Open Space Law provides authority for the Department of Conservation and Natural Resources, Department of Agriculture, and municipal governments to acquire open space to meet a broad range of objectives including biodiversity conservation.[8]
- The Pennsylvania Game Commission is authorized to acquire lands by purchase through the Game Fund or donation to add to the system of State Game Lands. Over the last two decades, PGC has been a major purchaser of lands in the state and now manages 1.4 million acres of game lands in 300 separate tracts. [8]
- The 2001 Conservation and Preservation Easement Act specifies that conservation easements can be created and held for a broad array of conservation purposes, including conserving natural resources and protecting wildlife. [8]
- Pennsylvania's Municipal Planning Code, Township Code, Environmental Improvement Compacts Law, and Open Space Law authorize acquisition of land by local governments and authorities. [8]
- PNDI is a partnership of two private conservation organizations – The Nature Conservancy and Western Pennsylvania Conservancy – and the Department of Conservation and Natural Resources. [8]
- The Pennsylvania Biodiversity Partnership is another example of a public-private partnership that combines the information and expertise from various interests to advance biodiversity conservation. [8]
- Land trusts that join together to provide maximum funding for land protection. [8]
- Coalitions of non-profit and for-profit organizations that team together to allow the for-profit partners limited development or resource utilization in exchange for funds to acquire title to biologically important lands or conservation easements. [8]

County and Local Government

Most land use planning and development decisions are made at the local level and thus county and local government initiatives are critical to the success of any statewide biodiversity conservation strategy. Each of Pennsylvania's 2,568 local governments has full authority over land use planning, zoning, and subdivision regulation. This makes coordination of land use planning and protection of biodiversity more difficult than it is in states where land use is regulated at a larger geographic scale, such as at the county level. [8]

Amendments to the state's Municipal Planning Code (MPC) provide opportunities for coordination between municipalities, which is important for biodiversity conservation since most factors influencing habitats and ecological communities occur at a scale that transcends municipal boundaries. Communities may now coordinate planning and land use decisions with one another without engaging in joint planning. The MPC amendments also authorize municipalities to enter into cooperative agreements to adopt joint comprehensive plans without giving up their separate zoning boards and planning commissions. Cooperating municipalities may designate "rural resource areas" in which uses like forestry and agriculture will be encouraged and enhanced. [8]

Resources cited

The following resources were used in compiling the current issue information required for study (pp. 1 – 36). The websites are provided for your information and further reading. You are not required to visit these sites.

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Learning Enhancement

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